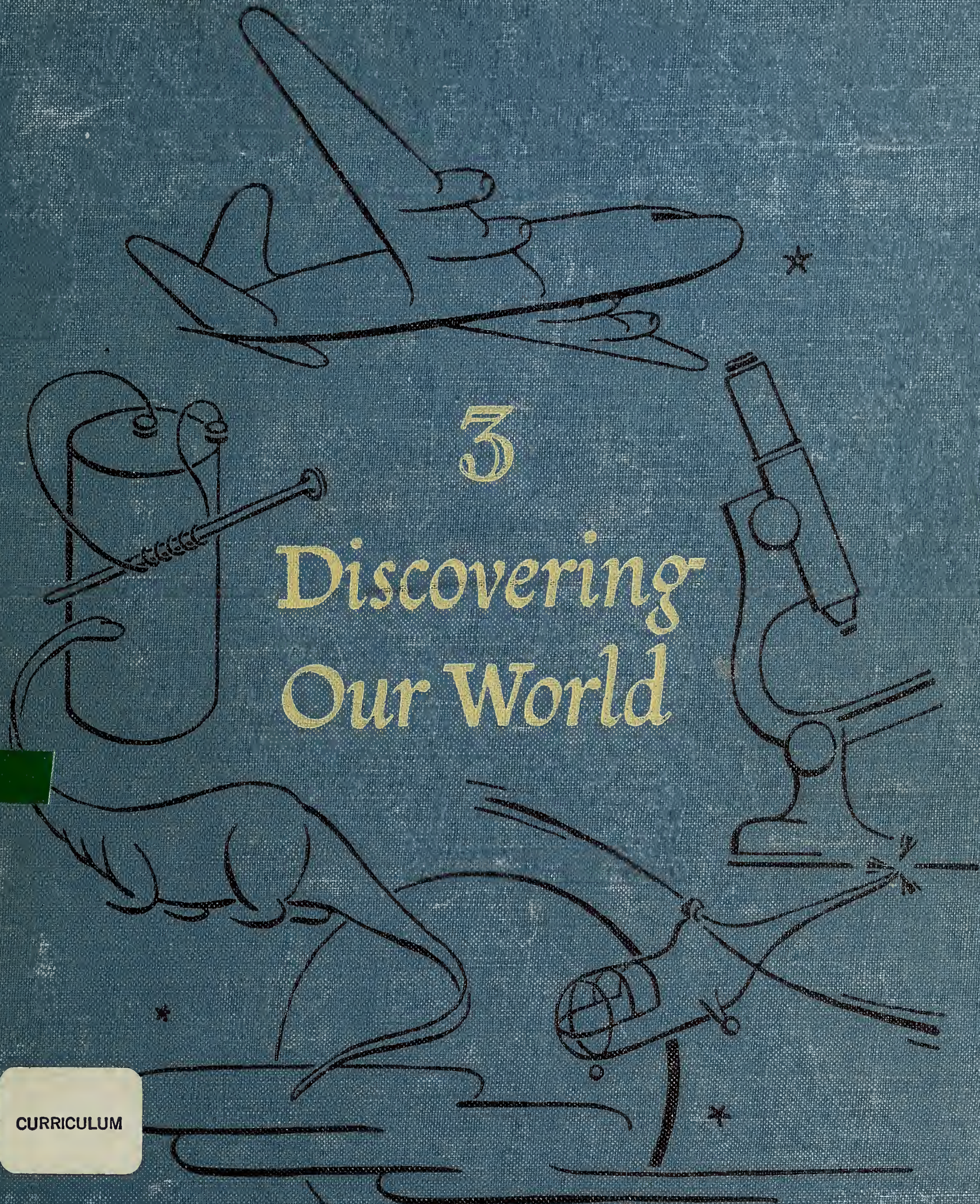

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Discovering Our World

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TEACHER'S GUIDEBOOK

FOR

Discovering Our World

BOOK 3

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SCOTT, FORESMAN AND COMPANY
CHICAGO ATLANTA DALLAS NEW YORK

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Preface

The impact of science on daily life emphasizes the need for an organized science program throughout the elementary grades. A new subject not many years ago, science now occupies an increasingly important place in the curriculum. Experienced teachers have discovered that science is not mysterious. It is no more difficult to teach than other subjects long taught in the elementary school. In fact, the child's natural curiosity about the world in which he lives makes science teaching easy. Motivation is never lacking in a properly conducted science class.

Yet many teachers, untrained in science, are fearful of science teaching. They suspect (often rightly) that pupils know more about science than teachers do. And they tremble at the thought of being asked a question that they cannot answer. These teachers lack confidence because they lack training in science. The purpose of this *Guidebook*, therefore, is to provide in-service training in science teaching. It is designed to help the inexperienced teacher learn as she teaches. Although intended primarily for teachers who lack the background and experience required for effective science teaching, the *Guidebook* also provides much information that will be useful for experienced science teachers.

Part One of the *Guidebook* discusses the philosophy of education and the technique of teaching used throughout the *Discovering Our World* series. It is divided into three main sections. The first section takes up the objectives of science teaching. The second covers the conditions of effective learning, the teaching cycle, and the organization of the series. The third deals with general methods for teaching science effectively. Part Two gives specific suggestions for teaching each unit in the pupil's book. Part Three is a book list. Part Four gives information about the care of animals and plants in the classroom, materials needed for the experiments and observations, and visual aids.

The usefulness of the *Guidebook* will be apparent to teachers acquainted with the books that precede or follow *Discovering Our World* in the *Basic Studies in Science* program. The suggestions have come from years of experience of the authors, their colleagues, and the teachers who kindly helped in shaping the book. The authors will be glad to receive additional suggestions for making this *Guidebook* a more effective teaching aid.

Why Teach Science?

Instruction that does not transfer over to life, providing a guide for behavior in the situations that arise, does not function. Therefore, the task of the teacher of science or of any subject is to determine what modifications of behavior can be brought about by that subject. A boy or girl who has studied science should be a different individual from the one who has not studied science.

The problem that every teacher of science must solve is: How can I so teach science that it will function as a way of living, as a mode of interpreting the world in which we live, as a way of reacting to our environment? Science so conceived is not simply a collection of facts about the various forces, materials, and phenomena of nature; it is a method of behavior.

If we analyze the ways in which a study of science will contribute to desirable modifications of behavior, we find five ways in which modification can be brought about.

1. The first way of modifying behavior through science is *by developing a genuine interest in the world of nature and a desire to know more about it.* A prerequisite to this interest is a rich background of experiences with the forces, materials, phenomena, and living things that make up the world in which we live. In this series, the authors have provided this rich background of experiences. They have also suggested activities that the child can carry on to discover more about the world in which he lives. A person who has acquired this interest has a never-ending source of satisfaction.

2. The second way in which the study of science can modify behavior is *through an understanding of the forces, phenomena, processes, materials, and living things that interact to produce the world in which we live.* Learning is essentially a process of acquiring meanings. When a thing, situation, or event has acquired meaning, it is understood. Perhaps the best statement of this idea has been given by Dewey: "To grasp the meaning of a thing, an event, or a situation is to see it in its relations to other things, to note how it operates or functions, what consequences follow from it, what causes it, and to what uses it can be put." Thus, one problem of the science teacher is to discover how the child acquires meanings.

A major type of learning in science is the acquisition of general concepts. Such general concepts cast a flood of meaning over the forces, phenomena, and materials of the environment with which the child comes in contact. Let us take an example. To identify a thing as a member of a certain group is to explain it, or to give it meaning. If we say that a thing is a "living thing," you know in general what kind of thing it is. You know that it carries on certain processes and activities. You know all this because you have acquired a general concept of what a living thing is. By means of such concepts, you are able to generalize, to carry over meaning from one situation to another.

In the teaching of science, we need to keep in mind the development of general concepts —concepts that may transfer to other situations and serve as a method of interpretation and explanation for particular things, events, and situations.

If you have studied science, you know that science generalizations are often stated as principles. For example, "Solids expand when heated and contract when cooled" is a statement of a principle. The principle tells you what happens when a certain condition is present. If you heat a solid (the condition), it will expand (the effect). A principle, therefore, is a statement of the relation between conditions and effects.

Since these principles are general in their operation, they interpret behavior and supply a guide for it in many situations. For example, consider the idea of gravitation. A baby takes a long time to discover the force of gravity. Through experience, he finally discovers that an object will fall unless there is some support beneath it. Then he may take great delight in dropping objects just to see if what happens will meet with his expectations. Finally, he generalizes and arrives at the conclusion that all objects must be held up by something, or they will fall. He has now acquired a method of behavior that enables him to deal successfully with situations in which the force of gravity is operating.

This example shows that a principle of science is not simply a collection of words to be memorized; it is the basis for a method of behavior. A person who understands a principle behaves differently from one who does not. He has a basis for explaining what he sees; that is, he can tell why something happens because he knows the conditions that are necessary to produce the effect which he observes. He can predict what will happen because he knows that certain conditions are followed by certain effects. He can bring about desired results because he knows the conditions necessary to bring them about. A person who understands a principle thus has the necessary basis for planning practical activities.

3. The third way in which modification of behavior may be obtained through science is *by developing the scientific attitude*. There are hundreds of superstitions fastened in the mind of the human race. Most of us are acquainted with people who firmly believe that breaking a mirror or walking under a ladder is a harbinger of bad luck. Probably none of these superstitions taken singly would seriously affect the life of any individual. Nevertheless, such beliefs are symptomatic of a condition that is very serious, namely, the lack of understanding of a most important contribution of science: a conviction of the universality of cause and effect.

A person who has the idea of cause and effect is entirely different from one who lacks this understanding. If he has this idea, he cannot possibly believe in superstitions, palmistry, or fortune telling by cards or tea leaves. All of these false notions fall down when examined in terms of a possible causal relationship.

This conviction of the universality of cause and effect is part of what is known as the *scientific attitude*. The holding of one's viewpoint as tentative until all the evidence is examined, the spirit of inquiry, and the habit of looking for problems to solve are also parts of the scientific attitude. A person in whom the scientific attitude has been developed has a distinct method of reacting to his environment—a method totally different from that of the person with no sense of scientific values.

Every available opportunity should be used to help children acquire the scientific attitude. Toward that end, they should be encouraged to become more observing, to look at a problem from every side before they express an opinion, to experiment carefully and accurately, to demand reliable sources of information, to withhold judgment until there is sufficient evidence to permit the drawing of conclusions, and to react intelligently to superstitious beliefs.

Children are vitally interested in science. As a result, they will ask many questions. This is a valuable part of the scientific attitude for both children and teacher. The teacher should not feel embarrassed if she does not know the answers to all of these questions. No scientist knows the answers to all the questions asked him. Any teacher of science will sometimes need to say to her pupils, "I do not know the answer, but I will be glad to help you find out." In fact, when the teacher knows the answer, she should not always tell it, especially if the question relates to something of basic importance. Rather, the teacher should help the children find the answer.

With such an attitude, the children and the teacher may solve coöperatively problems of mutual interest. A spirit of working together is most highly to be desired. The conclusions then seem doubly important, for the method of solving problems is no less important than the results obtained. Stimulate the pupils to do as much observing as possible. Let them examine things and arrive at their own conclusions. Try always to draw on their previous experience and on their observations made outside of the classroom.

4. The fourth way of modifying behavior is *by training in the scientific method of thinking.* The science class is the place *par excellence* for training pupils to become better thinkers. This is true because the generalizations of science are themselves the product of reflective thinking. It is possible in the science class to retrace, at least in part, the thinking through which the generalizations were reached. By using the experimental method of attack, we can set up situations where certain conditions are present and observe the effects produced. In the science class, pupils can make their own observations, draw their own inferences, and check the accuracy of their own conclusions.

5. The fifth way of modifying behavior is *by developing skills such as making observations, doing experiments, interpreting pictures and diagrams, reading science content with understanding, reading source materials,* and *using the instruments of scientists.* The *Basic Studies in Science* program includes a wide range of activities that are basic to the study of science. These are graded in difficulty so that each book in the program makes use of skills taught in earlier grades and then carries them on to higher levels of understanding and increased ability in their use.

Learning and Science Teaching

Conditions for effective learning

Methods of teaching must necessarily be based on the findings of psychology that deal with the learning process. These findings may be thought of as principles of learning that show the teacher what she must do to provide the conditions for effective learning. A brief statement of these principles and their application to methods of teaching science follows.

1. *Learning is most likely to occur when a child has a definite purpose to accomplish.* Instruction in science should be focused on a functional understanding of the generalizations of science that make the world meaningful. Somehow or other, we must make the acquisition of this understanding important to the child. It must meet some need that he has. Its acquisition must result in some satisfaction to the child. In other words, the understanding must solve some problem that he wants to solve, answer questions that he wants answered, or show him how to do something that he wants to do.

Application of this principle of learning must be made when starting a new unit or a new problem. It is a matter of setting the stage for learning. There are various ways of doing this. See pages 12-14 of this *Guidebook.*

2. *Activities must be set up that produce some active response by the child.* In science, we are concerned with certain understandings. We are trying to teach certain concepts that will help the child in his adjustment to the world in which he lives. Now a person cannot just learn an understanding. An understanding is obtained only when he does some thinking. Furthermore, if he acquires an understanding, it must be a product of his own thinking. We are all familiar with the saying, "We can't learn pupils, we can only teach them." In other words, as teachers, our task is to set up a learning situation in which pupils carry on certain activities focused on the understanding. The

pupil learns as he carries out the activities. The understanding that results is the pupil's. It is a product of his own activity. What the pupil does, therefore, determines what learning, if any, will occur. In general, the more active the participation of the pupil in deciding what should be done, the more purposeful the activity will be and, therefore, the more likely it will result in the desired learning product. The types of activities will vary with the learning product to be attained and with the kinds of materials available in the classroom.

This *Guidebook* is concerned primarily with the more effective use of the textbook. Suggestions for setting up desirable activities using text materials with different types of organizations will be found on pages 14-16 of this *Guidebook*. There are also many suggestions for doing experiments, taking field trips, etc. These suggestions will be found for the most part on pages 13-16 of this *Guidebook*. A discussion of "Using the pictures in the book" will be found on pages 17-18.

3. *Learning, to be effective, must be based on the experiences that the child has had or is having.* This implies that new concepts must be based on an adequate background of first-hand experiences. The more closely related the first-hand experiences of children are to the concept that is being developed, the more meaningful the concept will be. This principle is especially important in starting new units or new problems. Suggestions for its application are given on pages 12-14 of this *Guidebook*.

4. *The learning activities must be adapted to the individual needs of the child.* This means that a wide variety of activities should be carried on. Different activities attack concepts from different angles and thus obtain greater depth of meaning. Furthermore, some methods of development are more effective than others for different children. Reading, doing experiments, making observations, interpreting pictures, planning ways of finding out things, etc., call for different types of thinking. A many-angled approach is most likely to provide activities that are appropriate for children with different interests and abilities. Suggestions for different types of activities are included on pages 12-19 of the *Guidebook* and also in the procedures suggested for each unit.

5. *Learning, to be retained, must be used.* This principle has two implications. In the first place, it implies that activities must be set up which require the pupil to use the concept as a basis for explaining things around him and as a guide for practical activities. Only through use does the child acquire an understanding and the ability to use this understanding in his daily life. The more closely the kind of activity set up is related to the kind of situation that is met in daily life, the more likely it is that the learning will transfer to daily living.

In the second place, the principle implies the necessity for constant use of the concept and its reinterpretation in the light of new experiences. Old concepts must be constantly related to new concepts so that a continuous reconstruction of experience can take place.

In the pupil's book, common situations in the lives of children are used to introduce children to the problems. The examples applying the concepts are also of this type. In this way, the concept is related to life itself. Questions that children usually raise about the concepts are raised. Then the children are shown how to use the concepts to answer these questions or to do other things. The teacher should know what kinds of questions to ask children. Various types of questions will be found in the discussions of the different kinds of activities on pages 12-19 of the *Guidebook*.

The teaching cycle

The teaching cycle, to be effective, must parallel the method of thinking to be used in the learning cycle. It must insure that the child actually follows through the steps in thinking. This is done by setting up appropriate activities in each step of the cycle.

The principles of learning may be made more specific by showing how they are applied in teaching a generalization of science.

1. *There must be a stimulus to initiate learning.* In science, the stimulus must present a problem, because an understanding is obtained only through thinking. To present a problem, the situation must be meaningful to the learner; that is, it must be connected with some experience he has had or is having; and the situation must be sufficiently concrete and interesting to challenge the pupil to find a solution. Solving the problem is the purpose in the mind of the child. Ways of raising problems in the minds of pupils are discussed under "Starting a new unit or problem," page 12 of the *Guidebook*.

2. *There must be a period of assimilation or experience getting.* Pupils are sent to their textbook and other books, experiments are performed, field trips are taken. In fact, all sources that will supply needed facts and experiences are used. This period will always culminate in activities that require the pupils to generalize. Suggestions for using the book, performing experiments, and carrying on other activities are included on pages 12-19 of the *Guidebook*.

When a pupil has made the generalization, he has arrived at the point where he catches the idea; that is, he sees the relationship vaguely. If left at this point (and many teachers allow this to happen), he has not attained real learning. Therefore, the next step is extremely important.

3. *The generalization must be made meaningful.* This is a period of teacher-pupil activity in which the teacher tries to show some of the applications of the generalization: (1) how to use it, (2) where it is used, and (3) when it is used. In the text, applications of the generalization follow the development of the generalization. They take the form of new examples or problematic situations that are solved by use of the generalization. The specific suggestions for each unit provide additional examples to help make the generalization clear. This concludes the part of the teaching cycle in which the aim is to get across the understanding.

4. *Practice in the use of the new understanding must be provided.* The pupil must be provided with situations in which he uses the generalization for predicting, planning, and explaining. Since the understanding does not function unless it transfers to daily life, the situations must be common in the environment of the child. The greater the number of these situations, the more likely that the generalization will be functional in actual life. The questions at the ends of problems and units help provide these situations.

As a result of this step, the pupil arrives at a point of functional understanding. He can now use his understanding in situations appropriate to his level of development. In other words, he has arrived at a point of intelligent behavior. This method of developing a functional understanding is the method of thinking used by anyone who really carries on a complete act of thought.

Organization of this series

The *Discovering Our World* series is the result of a definite demand from teachers for a well-balanced, organized course in science, focused on acquiring meanings that will function in intelligent living. It is not just a collection of facts about bees, butterflies, and beavers. Interesting though these facts may be, they are not sufficiently general in their meaning to provide a basis for explaining the world or for solving our everyday problems.

In this series, the content is definitely focused on the acquisition of general meanings. These general meanings are developed by the problem method of attack. Problems, or questions, arise from, and thinking starts with, doubt or perplexity. A person has something to do or something that he wants explained; but he does not know what to do or how he can explain away his perplexity. This starts his mind searching for a way out of his difficulty. He begins to think. In general, the pattern of effective thinking is as follows:

1. Recognizing the problem to be solved.
2. Recalling experiences that may help to solve the problem.

3. Searching for new facts that may bear on the problem.

4. Evaluating the suggestions that come to mind and selecting the one that appears most promising.

5. Testing the suggestion for its truth.

6. Drawing a conclusion and testing the conclusion for its truth in other situations.

If study materials are to help pupils do better thinking, the materials must be organized and the ideas developed in such a manner that they follow this general pattern of effective thinking. For this reason, the problem method of attack has been used throughout the series.

Each unit deals with a major problem in the environment of the child. The unit, or major problem, is then broken down into minor problems. The solution of each minor problem is essential to, and leads toward, the solution of the major problem of the unit. A glance at a unit and its subdivisions in the table of Contents (pages 3-5 of the pupil's book) will show this. The child is confronted with a major problem. To solve this problem, he must think through minor problems. As he acquires an understanding of the generalizations and principles involved in each minor problem, he is building up an understanding of the major problem of the unit.

Each new idea in *Discovering Our World* is presented in such a manner that it becomes a problem for the child to solve. The text says to the young learner, "You have seen this happen, or you have had that happen to you. Now let's see if we can find out why it happened. First of all, just what did happen, and what were the conditions under which it happened?" This is no didactic, passive approach to learning. It is a pupil-activity, problem-solving approach: "Let's do something to see what we can find out in answer to our question." That is the spirit and the method of presenting and developing new ideas in the *Discovering Our World* series.

This treatment of science principles leads the child inductively, by experiments and observations, toward the acquisition and understanding of the principles. At every step, the spirit of problem solving, the spirit of discovery, is maintained. The organization, pictures, experiments, observations, exercises, and activities in the books of this series are focused on two objectives: (1) the development of meanings and (2) the development of better methods of thinking. This focus is maintained by a teaching technique based on problem solving. A child cannot *memorize* his way through these books; he must *think* his way through them.

How to Use This Book

Fitting the book to local conditions

The pupil's book includes enough material for those schools where full time is allowed for science as an established part of the curriculum. In such schools, the pupils probably will cover all of the units, including the questions and activities suggested. They may further enrich the science course by doing outside reading and engaging in additional activities according to their own interests.

In many school systems, science is introduced in the first grade. Children will, therefore, have many concepts that contribute to the understanding of the concepts presented in the text. To assist teachers in discovering this background, the authors have listed at the beginning of each unit, the background units found in the earlier books of the *Basic Studies in Science* program. Reference to these books will give teachers an idea of the experiences on which they can build the new concepts. Teachers are urged to become familiar with the concepts taught in preceding grades. In many cases, recalling these earlier experiences will bring about a decided saving in time. Furthermore, it will help pupils reinterpret these earlier experiences in the light of the more comprehensive concepts presented in the later grades.

In schools where time is limited, it may be necessary to shorten the course somewhat. This can best be done by covering some units rapidly, without stopping for detailed development, while others may be more carefully developed with all the suggested activities carried out. However, it is not wise to omit units or parts of units. A unit that is unrelated to others within a book may be necessary for the understanding of concepts presented in later books. For example, in Book One the unit on magnets (Unit 6) is not related to other units of Book One. But an understanding of magnets is presupposed in the unit on energy (Unit 2) in Book Two and in the unit on electric current (Unit 5) in Book Three. The section "Science background" in Part Two of the *Guidebook* shows the interrelationships of the units in the series. The series has been carefully planned as part of an organized program in science and is most satisfactorily used as such.

General suggestions for teaching the units

Many teachers have had little or no experience in teaching science. Yet science is not difficult to teach. First of all, children are vitally interested in science. This, of course, means that half the battle is won. The method used in teaching science is not greatly different from that used in other subjects where understanding of certain concepts is the goal. However, science teaching makes greater use of observations, field trips, and experiments than is ordinarily made in other subjects. The science activities in the middle grades are very simple. The equipment consists of easily available materials. The directions given in the text, together with pictures that show the materials used and how they are put together, are so detailed that a teacher who knows little or nothing about science will have no difficulty in doing the experiments or carrying out the other activities.

Needless to say, the ideal learning situation is one in which the teacher enlists the active coöperation of her pupils in planning and carrying out the activities of the various units. The following general suggestions will be helpful in achieving this ideal situation. (Specific suggestions will be found in Part Two of the *Guidebook*, which deals with individual units.)

1. Interest pupils in an active program of observing and collecting as much material as possible from their surroundings.
2. Encourage boys and girls to suggest additional experiments, field trips, and observations.

In this section of the *Guidebook*, the authors have set up general principles for using the book and for carrying out the types of activities suggested in the book. These general principles should be applied in teaching specific units. Once a teacher understands the general principles and sees how they are applied in concrete situations, she will soon gain skill in applying the principles in new lessons. Of course, many teachers do not need a discussion of this type. This section is written especially for those teachers who are a little uneasy about their ability to teach science.

Preparing to teach

First of all, the teacher must have clearly in mind the science generalization that she is trying to teach. She can use the list of concepts in Part Two of this *Guidebook* to find out what these important generalizations are. As she uses the text, she must learn to differentiate between the facts, examples, and other assimilative materials and the generalization itself. An inexperienced teacher may easily fail to do this. Therefore, she does not see that the text is focused on getting across a certain concept. As a result, the activities set up in the classroom lack focus because the teacher has none. As a first step in preparing to teach, therefore, the teacher should find out what is the big idea, understanding, or generalization that she is supposed to get across. To help her see what the general concepts are, the authors have listed them at the beginning of each unit. In addition to this, the authors have listed the concepts for each subdivision, or problem, of each unit.

With her *Guidebook* open to these lists, the teacher should read through the unit as a whole and again through each problem before presenting it. She will then have a clear idea of the scope of the unit and also of the contribution that the concepts in each problem make to the unit as a whole. She will also have a clear picture of the relation of the observations, experiments, and other activities to the development of the concepts. She will be able to plan ahead for time and materials when necessary. Specific suggestions for planning ahead will be found in the sections called "Procedure" in Part Two of the *Guidebook*.

During the initial preparation for teaching the unit, the teacher should also look ahead to the additional activities suggested in the "Things to Do" sections at the ends of the units. Some of the activities are related to the unit as a whole. Others pertain to certain problems and are referred to in the procedure for the problem. Since it is better to use these activities throughout the unit rather than to wait until the unit has been completed, the teacher should look ahead and plan for the ones that she can use.

Second, the teacher must find out what experiences the children have had that can be explained by the concept. By questioning the class, the teacher should be able to discover just how far the pupils have advanced toward an understanding of the concept. However, if they have had no appropriate experiences, the concept cannot be taught until such experiences have been acquired. An experiment, observation, or field trip will often provide the needed experiences.

Because of the limited science training of many elementary teachers, the authors have included some of the technical science background behind the elementary presentation of the text. This will be found in the sections entitled "Information for the teacher" in Part Two of the *Guidebook*. Teachers should also consult standard high-school texts in biology and general science. These will give the desired information without going into needless technical detail. They will also give some additional background as a preparation for teaching the unit.

General procedures

Starting a new unit or problem

The first teaching situation met in a new unit or problem is naturally that of deciding how to get started. Shall I have the pupils read the introductory section first? Shall I raise some questions before sending them to the book? If so, what kinds of questions shall I ask? Shall I start with a field trip or a demonstration? Shall I tell them a story? What shall I do?

As pointed out earlier in this *Guidebook*, learning begins when the pupil starts to think. His thinking starts when he is faced with a situation in which he is not certain of exactly what to do or when something happens that he does not understand and he wonders "Why?" or "How?" In other words, thinking starts with a doubt or perplexity. There must, however, be more than a perplexity; the pupil must also want to do something about it.

All of this means that the pupil must have a question before he will begin to think and that he must want to answer this question. To start a new unit or problem, the teacher must be certain that the pupil has questions which he wants answered. He may want to find answers to his question because he sees their use value or because they provide for some definite need or simply because his interest is challenged and he wants to know. Any of these reasons are equally good for raising questions. The important thing is to be certain that the child has some questions which he wants answered.

Questions arise when a person is in doubt. No concrete question can arise, however, unless it is related to some past experience or present experience. This is true because the meanings that we have are the results of our experiences. Without experiences to give us meanings, we cannot have questions because we do not know enough. We can only be confused. We cannot put our finger precisely upon the perplexity, and so we cannot start to think. To start a new unit or problem, therefore, the teacher must relate the unit to past experiences of the pupils or to experiences that they are now having. These experiences must lead into questions that the children cannot answer. Here are some of the methods in which a new unit can be started. (Most of these methods can also be used to start new problems within the unit.)

1. *Ask questions about experiences that the pupils have had which may be related to the unit.* To use this approach, first make a list of what children have probably seen, heard about, read about, or done. Then ask questions such as: "Did you ever see——?" "What did it look like?" "Have you ever heard about——?" "Did you ever make a——?" "Did you ever watch someone——?" The purpose of these questions is to get some facts from the pupils' past experiences. The questions will also bring to light experiences that the pupils would never voluntarily recall because they would not see the relation of the experiences to the new unit.

Now you are ready to raise questions. Accordingly, ask questions about the "how" and "why" of these experiences. "How do you explain this?" "What made this happen?" "Why did you do——in this way?" Use questions such as these to push the pupils back further and further until you come to explanations that they cannot make. Write on the board questions that they cannot answer under the heading *Questions We Cannot Answer.*

With these questions in mind, the children can read the introductory section of the unit to see if they can find any answers to their questions. Often the introductory section raises new questions. If the children cannot answer them, they should be added to the list on the board. (Example: Unit 4, page 95.)

2. *Compare experiences of pupils with experiences presented in the text.* The introductory sections of some units present experiences that are used to raise questions. If children have had similar experiences, ask questions about them. Have the children tell how they did a certain thing or describe something they have seen. If a series of steps is involved, write them on the board.

Then refer children to the book and say, "Here is a story that tells you how someone else did this." Have pupils read to find out what was done. Tell them you are going to ask them to tell the class, step by step, what was done. Write these steps on the board. Then have pupils compare these steps with the steps that they have listed. Then ask for reasons for the various steps. This should result in questions that the pupils cannot answer. (Example: Unit 1, pages 9-10.)

3. *Use pictures to start discussion of the unit.* Have pupils read the unit title. Then ask questions about pictures in the unit that will lead into the first problem. (Example: Unit 2, pages 33-59.)

4. *Have pupils read the unit title.* Then ask them to read the problem titles to find out what kinds of questions are to be answered. Write the problem titles on the board and ask pupils what they think the answer to each one is. This procedure will help create interest in the unit and at the same time will give an idea of the scope of the unit; it may be used with almost any unit. (Example: Unit 8, pages 215-232.)

5. *Use the introductory section to initiate activities that will result in a question.* In some of the units, the introductory section sets up activities that will raise questions. The text describes how a group went about finding an answer to a question. First, have pupils read the unit title. Then tell them that the introductory

section tells what one group did to get started. Have them read the section to find out what this group did. Next, ask questions about what this group did. Then have the pupils plan how they can carry on the same activity. After the materials have been brought in, raise the questions to be answered in the first problem. The pupils should now be asked to tell what they think should be done to answer the question. Then compare this solution with the method suggested in the text. (Example: Unit 1, pages 9-10.)

6. *Do some experiments.* (These can be experiments suggested by the book or experiments not in the book. The purpose is to raise some questions.) A good way to start a unit is to get some facts that require explanation. This method is often used in the text. Have the pupils read the unit title. Then tell them that the introductory section tells how to do an experiment to get some facts. Ask them to read the section to find out how to do the experiment. Next, have the children tell how to do the experiment or have some member of the class do the experiment. Then make a list of the facts brought out by the experiment. Call for explanations of these facts. Make a list of questions about facts that cannot be explained. (Example: Unit 9, page 241.)

7. *Take a field trip to get some facts to explain.* Whenever possible, the pupils should get facts by first-hand observation. Since the units in this book are related to common environmental situations, children can often be taken on walks or trips where they can make observations and thus get facts that call for explanation. To find out what to observe and what kinds of questions to ask, read the problems of the unit and note the pictures and their legends. Then take a walk yourself to find out what things can be seen. Make a list of the things and the questions you can ask about them. (Example: Unit 3, pages 61-62.)

Using the text to get ideas needed to answer questions

In general, the text uses three methods of organizing the study material: (1) It may tell how one class answered the question. (2) It may answer the question by telling the pupils how to carry on certain activities. (3) It may answer the question by straight exposition. The method of using the text will necessarily vary with the method of presentation used in the text.

1. *The text presents a class discussion.* In this type of presentation, the text presents a running account of a classroom discussion. This method is used principally in the opening unit of the book to show how a science class might be conducted. The teacher asks and answers questions; pupils answer questions and ask questions; the teacher guides the discussion toward an understanding of the concepts that she is trying to get across by her questions and her follow-up of the pupils' answers. This type of presentation has several purposes.

First, it presents a pattern for carrying on a discussion in a science class. Teachers who have had no experience in teaching science will find it profitable to read through several lessons of this type to get a better idea of the kinds of questions asked by the teacher to keep the discussion going and the ways in which the pupils are brought into the discussion. Note that the pupils are asked to suggest ways of doing things and that these ways are discussed and evaluated by the pupils.

Second, the children, as well as the teacher, must learn to participate in a classroom discussion. Unit 1, Book Three, is developed largely by this method so that pupils may be introduced to the type of thinking that goes on in a science class. The teacher might well say, "The class described in our text is carrying on a discussion. Let's see how they do this so that we'll learn how to discuss, too."

Third, presentation of this type adds interest to the text because children are interested in what other children do. They are also interested in carrying on the types of activities suggested in the text.

Fourth, this type of presentation permits a slow and easy development of the concepts.

Each step in the development of the concept is included. The children can easily follow the thinking of the class and see how the class arrived at the concept. There are several methods of using this type of material; the method to be used depends on the way in which the material is developed and the purpose.

a) The purpose is to initiate an activity in the class. To do this, the text describes what one class did. For example, let us suppose that pupils have brought various kinds of things to school. The teacher raises a question, "How can we find out more about these things? Let us see what the class in our text did." After the pupils have read the text to find out what the class did, the teacher asks questions such as: "What was the class trying to find out?" "What did they do to answer the question?" "Why did they decide to do this?" "Could we do this?" "How could we do this?"

As can be seen from the questions, the major purpose is to show the pupils what they can do. The suggested activity should be carried on whenever possible. While it may be possible to get an understanding merely by reading and discussing the text, there is no substitute for actual experience. Note that the questions asked by the teacher call for more than repeating what the text says. They raise questions about the "how" and the "why" of the activity. (Example: Unit 1, pages 24-29.)

b) Sometimes it is better to raise a question and either suggest or have the pupils suggest what they might do to answer it. Then have the pupils go as far as they can in answering the question. The children can then be referred to the text to find out if the class described answered the question in the same way or in a different way. Then have the children find the ways in which their answer was like or different from what the class in the text found. (Example: Unit 1, pages 9-10.)

c) As a rule, pictures are included that show how the class described carried on the activity or that show the finished product of their activity. The teacher asks questions such as: "What is the class doing?" "Why are they doing this?" "Can we do this?" "How did they do this?" before the pupils read the text. Rediscussion of the pictures on the basis of what the pupils find out can follow. (Example: Unit 1, pages 10-12.)

2. *The concepts are developed by raising questions and answering these questions by making observations and doing experiments.* Science differs from the other subjects studied in the elementary school in that the questions which arise can be answered by observation and experiment. Through the use of these two activities, the pupils can get first-hand information. They can then base their thinking on facts that are meaningful to them. Throughout this book, experiments and observations have been introduced wherever possible. This has been done for two reasons: (1) because all learning focused on understanding must be based on a background of perceptual experiences, that is, on information that the pupil can get with his own senses; and (2) because pupils should acquire the attitude, "If we have questions or want to find out about something, we can do experiments (or make observations) that will answer our questions."

Experiments and observations are introduced in this book to provide facts that are needed to answer some questions. A statement in the text is made more meaningful by doing an experiment or making an observation. Or the experiment is done or the observation made to answer a question that has been raised in the text just preceding the experiment.

Before the text is read, the teacher should (1) raise questions about past experiences of pupils such as were suggested in the section dealing with starting a new unit and (2) raise the question that the experiment or observation is to answer. Then ask the children, "How can we do an experiment to find out?" (It is always good practice to have children suggest possible ways of doing an experiment. Many of them may be good enough to try.)

Now that the question is raised, the children can be referred to the book for directions. The teacher can say, "Our book tells us how to do an experiment to answer our question. After you read the directions, I am going to ask you to decide what to do." Write *What to do* on the board and then have the children tell what directions to write.

Make the directions as brief as possible. If a simple diagram can be made, have pupils tell how to make the drawing. If they do not know, show them. This is valuable because pupils have to learn how to interpret diagrams. Practice in making diagrams will help them learn how to interpret diagrams.

Now ask the pupils what they think will happen. Get them to predict. This is effective because (1) you can ascertain from their answers whether or not they understand what is going to be done; (2) you can see if they know what to look for; (3) you can make them commit themselves and make them interested in seeing whether they are right or wrong.

Next, get them to understand what the experiment will show if a certain thing happens when the experiment is performed. Ask them, "If——happens, what will this show?" Then do the experiment. Write on the board *What happens.* Have the children decide what to write. Then raise the question, "What does this seem to show?" Write *What the experiment shows* on the board. Have the children tell what to write.

Whenever possible, the step of verification should be used. Ask, "Is there any experiment we can do to prove that we are right?" In many cases, such an experiment is included in the text. If this is the case, have the children read the experiment and record the results under the steps already listed. Then have the children work out a conclusion. The conclusion should answer the question and give reasons for the answer.

After all of the experiments have been performed, raise the questions, "What facts do our experiments give us that we can use to answer our question?" "What facts does the book give us?" The facts from both sources should be incorporated into the answer for the problem. (Example: Unit 1, pages 15-17.)

3. *Concepts are developed by raising questions and answering these questions through presentation of reading material of a descriptive nature.* Whenever possible, experiments and observations are used to develop the science concepts. Sometimes, however, it is impossible to provide experiments that are sufficiently simple to be carried on by middle-grade children or that do not require laboratory facilities beyond the resources of the elementary school. It is equally impossible to provide for actual observation of all living things in their natural habitats. Accordingly, the text must provide factual material based on the observations of scientists. It should be emphasized that the facts have been acquired by experimentation and observation. This point of view can be developed by asking such questions as "How do you suppose that scientists found out about this?" "What might we do to prove this?" "Why can we believe that this is true?"

The method of developing the concept, of course, depends on the kinds of concepts that are being developed. For example, if the content is focused on showing the children how some device works, the development will be somewhat as follows: (1) what the device does, (2) how it is put together, (3) how it is made to work, and (4) an explanation of what happens when the device is operated. If the content is focused on the development of the characteristics of a group of living things, materials, etc., various members of the group are described; and then the characteristics common to all members of the group are discussed. If the concept is focused on some relationship, specific examples of the relationship are presented; and then generalizations are made about this relationship.

The pupil's book provides the necessary information. It should be pointed out here that the facts included in the book are a means to acquiring the concept. The ability to repeat verbatim what the book says does not necessarily mean that the child has acquired the idea. Suggestions for developing the concepts are found under the heading "Procedure" in each problem of the *Guidebook*.

Using the pictures in the book

In *Discovering Our World, Book Three*, as in all the books of the *Basic Studies in Science* program, the pictures are functional. They are an essential part of the method of developing the concept. Each picture has a definite purpose to serve. For example, some pictures are used to raise questions, some are used to show steps in a process, some are used to show how an experiment should be performed, some are used to supply additional applications of a process, and some are used to provide for practice in interpreting. Pictures may be a substitute for the actual experience. They make it possible for the child to experience vicariously the experiences that others have had. They bring the near and far environment into the classroom.

To use the pictures effectively, the teacher must study each picture to see how it can be used to assist in learning. First, she should understand what the purpose of the picture is. Then the question is, "How can the picture be used for this purpose?" This is a matter of determining what questions to ask about it or what activities to set up that will make the picture serve its purpose. The following examples show how to use pictures in this manner.

1. *Using pictures to raise questions.* Pictures used for this purpose usually have the legend in the form of a question. The problem may be introduced by asking pupils to look at the picture and answer the question. Then they may be directed to read the problem title and the text to find out if their answer to the question was correct. The original answer can then be corrected in light of what they have found out from their study. If the original answer is incorrect or partially incorrect, the children should be asked why it was incorrect. (Examples: Unit 3, pages 68, 69, 70.)

2. *Using pictures to show how to carry on some activity.* The text describes an experiment to perform or an observation to make. The picture shows some children carrying on the activity. The purpose is to help pupils see how the activity is carried on. There are several ways of using these pictures.

a) Have the children read through the directions in the text. Then refer to the picture. Ask questions such as: "What things is the boy using?" "What is he doing?" "What is he trying to find out?" "Can we do this experiment?" "What shall we do?" (Example: Unit 1, pages 16-17.)

b) After the question is raised, have the children look at the picture before reading the text for directions. Then ask questions such as those above. Then have the children read the text to find out more exactly what the boy is trying to find out, what materials he needs, and what he is doing. (Example: Unit 6, page 162.)

c) Sometimes the materials and equipment in the picture may not be available in the school. In this case, the picture can be substituted for the direct experience. In some cases, other kinds of materials or equipment can be used. Ask children how they might do the experiment with other equipment that is available. (Examples: Unit 2, page 37; Unit 4, page 113; Unit 10, page 280.)

Often the pictures merely show the apparatus needed and methods of constructing the apparatus. It is necessary to refer to the text to find the directions for doing the experiment. Ask questions such as: "What do we need to do the experiment?" "How shall we put the parts together?" "What do the pictures tell us to do?" Examination of the picture should be followed by having the pupils read the text to check the information that they get from the picture. (Example: Unit 5, pages 147-148.)

3. *Using pictures to make graphic a concept developed in the text.* Without a picture, description is often difficult to understand. Pupils cannot always visualize what is described. Pictures also make it possible to show things that the child has not experienced or could not experience in his everyday environment. For example, the pictures on pages 248 and 249, Unit 9, show the sequence of events. Questions about

the pictures should connect what is shown to the concept. Questions such as the following can be used: "What do these pictures show?" "What does the book tell us about these pictures?" "What do these pictures show about plants?"

4. *Using pictures to obtain interpretation on the basis of a concept that is presented.* An essential part of all learning is use of what has been learned. Use of a concept in the interpretation of a picture helps make the concept more meaningful. Many pictures of this type are included in the book. Usually there is a legend with a question. Or a question may be included at the end of the problem. (Examples: Unit 3, page 69, No. 4; page 72, legend under picture; Unit 4, page 107, No. 4; page 115, legend under picture; Unit 10, page 289, No. 6.)

Without the use of pictures, it is almost impossible to teach how a device is constructed. Children find it difficult to visualize a long description of the parts of a device and the relation of these parts to each other. The following questions will help pupils analyze the device and see how it works: "What is the name of the device?" "What does it do?" "What are its parts?" "About how large is a real device of this kind?" "When this part moves, what does that part do?" "What are the different steps in its operation?" "What happens in each step?" "How can we explain what happens?" "Where is this device used?" "Who uses a device such as this?" "Have you ever used a device like this?" "What for?" "How should the device be taken care of?" (Examples: Unit 6, pages 171 and 182.) Pictures of parts of plants and how they work are used in this way also. (Examples: Unit 9, pages 245, 254, 255.)

Using the questions at the ends of problems

The questions found at the ends of the problems also are focused on the important concepts. The final step in each problem is to have the children answer the questions raised at the beginning of each problem. Usually, it is worthwhile to write an outline answer on the board. The outline should be developed by the children. In general, it should correspond closely with the outline of concepts presented in the *Guidebook*. If children fail to include a certain concept, the teacher should raise questions that will bring out the concept. For example: "You remember we read about——. What does this show? How do these facts help us answer our question?" Or the children may be asked to reread some part of the problem and the questions above may be asked.

The activity at the end of each problem is a generalizing activity. The children must be led to see that the facts presented in the book are important because they enable the children to get ideas about things that can be used to find out more about other things. For example, when the pupils find that mammals have certain characteristics, these characteristics tell them about other mammals and also help them decide if a certain animal is a mammal.

The questions at the ends of problems are of two types. The first of these two types is designed to test the child's understanding of the study material. Questions of this type can be answered if the child understands what he has read. They correspond roughly with the questions used to test reading comprehension in standardized tests. The second type of question calls for some thinking on the part of the child. It may require the recall of experiences similar to those presented; it may call for classification of objects or events based on certain group characteristics; it may call for the interpretation of a picture on the basis of some concept that has been studied; it may call for comparisons; or it may call for reasons for carrying on an activity in a certain way. These questions are designed to give the children practice in the use of the concept.

The questions may be used in several ways. After the problem title has been read, the children can be referred to the questions at the end of the problem to find out what they must be able to answer after they have studied the text. It is often desirable to have them try to answer the questions before the text is studied. After studying the text, they can compare their original answers with the ones that they now give. This method of study shows the children that they have learned something; they can answer questions that they could not answer before.

Or the text may be studied before reading the questions. Then read the first question to the children and call for an answer. This may be given orally or sometimes in writing. The teacher should distinguish between the information-type questions and the application-type questions. Children are accustomed mainly to questions that can be answered directly by the recall of something which they have studied. When an application-type question is asked, they should be told that they will have to think out the answer because it is not in the text. Occasionally, when they cannot get started on the answer, the teacher may have to ask them what they learned from their study. This might be written on the board. Then say, "How does this help us answer our question?" They must understand that what they learn can be used to answer other questions.

The information-type questions at the ends of the problems can also be used as a basis for a summary. First, write the problem title on the board. Then call for the answers to the questions. Write the answers on the board as briefly as possible. Then help the children condense the answers to the different questions into a single answer to the problem.

Using the "Questions to Answer" at the ends of units

The "Questions to Answer" at the ends of units are so stated as to require a broader association of meanings than is called for by questions at the end of each problem. They call for integration of ideas obtained from different problems and for interpretation of situations on the basis of ideas obtained from the whole unit.

The "Questions to Answer" should be discussed after the problems of the unit have been completed. Children should learn to give evidence for their answers. One method of stressing this is to have children be prepared to cite references in the text, which they used as a basis for their answers. When they start finding the answers to the questions, tell them to look back through the unit and find a paragraph, a sentence, or a picture which they can use to prove that their answer is correct. Then ask them how this reference in the text can be used as proof for their answer.

Since some of the questions are of the application type, children may sometimes have difficulty in answering these questions because they fail to see the connection between the text and the question. If this happens, refer them to the part of the text dealing with the idea basic to the solution. Have them read it over and then ask, "How can we use this idea to help us answer our question?" Every question in the book can be answered by using what the children have studied.

Using the "Things to Do" at the ends of units

The "Things to Do" at the ends of units suggest activities that make more meaningful the ideas in the units and bring about a closer tie-up with the environment. Usually, the activities should be assigned to individuals or groups on a voluntary basis. Some time should be spent in class, planning how an activity should be carried out. This should be as nearly pupil activity as possible, for the planning has the greatest value. Sometimes a group can be instructed to plan what they intend to do and then report back to the class on their plans. Then the plans can be evaluated and changed by the children. In this way, all the children will learn how to plan science activities; and they will get a better insight into the method used by scientists.

Part Two SUGGESTIONS FOR TEACHING THE UNITS

This part of the *Guidebook* gives specific information and suggestions for teaching the individual units. If the teacher has read Part One carefully, she has become acquainted with the general suggestions for handling the various types of teaching situations that will arise in teaching the units. As she comes to these situations (starting new units or problems, doing experiments, etc.), she should refer to the appropriate section in Part One. Application of these general suggestions, together with the specific suggestions that are given for the section being studied, will help the teacher approach the situation with confidence.

Using the Introduction (Pages 6-7)

By the time boys and girls enter the sixth grade, the world around them is assuming a more fascinating form because their fund of knowledge, both from books and from experience, has so grown as to give them a more understanding attitude toward what they see. They have developed interests and hobbies, many of which can be used to increase their curiosity about science and to help develop skills that are valuable in studying science. Such a hobby, for example, is the making of model planes, which is of great interest to both boys and girls. Developing the understanding of what makes a plane fly, offers an excellent opportunity to show how the principles learned in the classroom are applied to situations in everyday life.

Working with their hobbies brings out again that it is not necessary to go far from home to "discover a bigger world." If the members of each science class explore the possibilities of their own community, they will find many opportunities for developing interests. Parks, museums, forest preserves, manufacturing plants, power plants, waterworks, etc., will help city children become as well acquainted with the world around them as children who live in or near the country.

And further, these hobbies, if carried out constructively, will give new meaning to the attempt to develop a scientific way of solving problems. The requirements for good experimenting have been stressed in earlier books of the *Discovering Our World* series. But these rules can be given new meaning by asking how they apply, for example, to making a model plane that will fly. Perhaps some boys are interested in other machines, or girls are having their first experiences with cooking. Any of these interests can be used to concrete the ideas in column two of page 7 by bringing out in discussion how following these rules can lead to the desired results.

On page 6, note the reference to the table of contents. It is worth while to spend a few minutes going over the contents to give the children a bird's-eye view of the year's work. Brief mention should be made of the list of Science Words on page 295 and of the Index on page 299, even though from prior experience with the *Discovering Our World* books, the children may be familiar with these features.

UNIT 1. *What Makes Sound?*

Purpose and scope

This unit presents simple explanations for many of the things that pupils observe about sounds in their environment. It will broaden their interests in this phenomenon and give plenty of opportunity for first-hand contacts with sound. The pupils who take music lessons will have much to offer to their classmates. They should be urged to bring their musical instruments to class and to demonstrate how these instruments make sounds and how the sounds can be changed. There are many opportunities for individual investigations and experiments by interested pupils. The subject of sound, in all probability, is new to most of the pupils and perhaps even to the teacher. The text is kept simple and non-technical for this reason.

Before proceeding far in the unit, the teacher will do well to look ahead and work out with the pupils a schedule for bringing things (musical instruments, etc.) to class as well as for constructing simple experimental equipment.

Science background

Discovering Our World, Book One: Unit 3, How Does Your Body Work? Unit 7, How Can You Keep Well?

General concepts

1. All sound is made by vibration.
2. Sound travels by vibrations in the air, called sound waves.
3. The pitch of a sound depends on the speed of vibration. The faster a material vibrates, the higher the sound it produces.
4. The highness or lowness of a sound depends on how hard the object is vibrating, that is, how far back and forth it is moving. A material can be made to vibrate with more force by striking it harder.
5. All musical instruments produce sounds by making the air vibrate.
6. We hear sounds because the sound waves travel to our ears and make the inner parts vibrate. Nerves carry the message of the vibrations to the brain, which interprets them into meanings.
7. It is very important to take good care of our ears.

Introducing the unit (Pages 9-10)

Experiments

PAGES 9-10: To observe different kinds of sound makers.

MATERIALS: Ruler, triangle, rubber band, tuning fork, etc.

Information for the teacher

A general science book or physics book will give additional background for the understanding of the phenomena of sounds. Also see Bibliography on page 108 of the *Guidebook*.

Procedure

The procedure suggested on page 9 of having each pupil bring one sound-making thing to class is a good way to begin the unit. The simple demonstrations with a ruler, rubber band, triangle, etc., may be done as suggested in the book. Have the children read pages 9-10. Then the questions at the ends of the first and second paragraphs on page 10 may be discussed as a preliminary to the first problem in the unit.

How are all sounds alike? (Pages 10-12)

Concept

All sound is made by vibration.

Experiments

PAGES 10-11: To observe that the prongs of a tuning fork vibrate when they are struck.

MATERIALS: Tuning fork (small size), pan or dish of water; tuning fork, piece of cork, thread, needle.

PAGE 11: To observe what happens when a rubber band stops vibrating.

MATERIAL: Rubber band.

Procedure

This first problem helps pupils learn that sounds are produced by vibrations. To introduce the problem, have the pupils do the two experiments pictured at the top of page 11. Each pupil should have these simple experiences himself, if possible, either during class or out of class. Let pupils observe carefully and report their observations. They should then read the paragraph that explains the meaning of vibrations and perform the experiment with the rubber band. To check their findings, have the pupils read and discuss the text.

Questions (Page 12)

1. Move back and forth very fast. Pulling or striking.
2. Touch it.
3. All are vibrating. A tuning fork that is making sound will splatter water or will move a cork that is hanging near it.

How do living things make sounds? (Pages 12-14)

Concepts

1. In people and most higher animals, sound is produced by vibration of vocal cords.
2. In many insects, sound is made by vibration of wing parts.

Experiment

PAGE 13: To show how moving air causes vibration.

MATERIALS: Blades of grass or small strips of paper or cellophane.

Information for the teacher

PICTURES. PAGE 12. The voice box is the larynx. The vocal cords stretch across the larynx.

PAGE 13. *Left.* Frogs have vocal cords. The sac on the throat, called a vocal sac, acts as a resonator, which makes the sound louder. *Right.* This species of click beetle is called the Eyed Elator because of the two large black marks that resemble eyes.

Procedure

"How do you make sound?" might be discussed by the class in preparation for reading these pages. Let pupils hum a tune and feel their throats as they do so. The experience of saying the alphabet will help pupils gain a clearer picture of how they produce sound. If possible, have pupils observe some of the common sound-making insects and try to see how they produce sounds. If this is not possible, let them study the pictures on pages 13 and 14. Then they should read pages 12-14 to clarify the ideas. See also *Things to Do*, page 31, Nos. 1, 3, and 10.

Questions (Page 14)

1. *You:* by vibrating the vocal cords in your voice box. *Bird:* by vibrating its vocal cords. *Katydid:* by rubbing its wings together. *Bee:* by moving its wings up and down very rapidly.
2. All are caused by something vibrating.
3. High or low, soft or loud.
4. By using teeth, lips, and tongue with the help of the brain.

How do sounds travel? (Pages 15-17)

Concepts

Sound travels by vibrations in the air called sound waves.

a) Sound waves travel in all directions from a thing that is vibrating.

b) Sound waves travel through solids, liquids, and gases.

c) Sound travels at a speed of about 1100 feet per second in the air.

Experiments

PAGE 15: To show that sound waves travel through the air.

MATERIALS: Two tuning forks (small size), two small wooden boxes open at one end, stick, rubber stopper or cork.

PAGES 15-16: To show that sound waves travel in all directions.

MATERIAL: Bell.

PAGES 16-17: To find out whether sound travels in solid materials.

MATERIALS: Yardstick, tuning fork, piece of cloth.

Procedure

Have the pupils do the experiment with the two boxes described on page 15 to find out that sound does travel through air. The experience described with the bell will also make real the idea that sound travels in all directions from its source.

After doing these things, pupils may read the experiences of the boys who were in swimming. In preparation for that, the pupils may try to answer this question: "Can sounds travel through water?" After this discussion, pupils may wish to try a similar experience, if there is a swimming pool available.

To see if sounds travel through solids, have pupils do the experiments described on pages 16-17. A necktie works well for the experiment suggested at the top of page 17. After the pupils have done these experiments, have them read and discuss the remainder of the problem.

Questions (Page 17)

1. By making something vibrate so that the air near it vibrates.
2. Without air around the bell, sound waves cannot travel from the bell to you.
3. Describe the experiment with tuning forks on page 15 or with a yardstick and tuning fork on pages 16-17; tell about Henry and the radiator signal, about Bob and Jerry's experience with the rocks in the water, or about sounds that can be heard clearly by putting an ear to the ground.
4. Hard solids. Liquids.
5. About 15 seconds.

How can we control sound waves? (Pages 18-19)

Concepts

1. Sound waves can be guided to travel in certain directions.
2. Sound waves can be reflected to make an echo.
3. Echoes in rooms can be prevented by using special materials on the walls and ceilings.

Experiments

PAGE 18: To show that sound waves can be guided.

MATERIALS: Megaphone or piece of cardboard, watch.

Procedure

The experiences with the megaphone described here will help pupils understand how sounds may be controlled. They have probably all had experiences with echoes. Pupils will be interested in finding out how the school auditorium and the other public rooms that they use are made free from echoes. Samples of different kinds of sound-proofing materials might be examined. Have the pupils read pages 18-19 to check their findings.

Questions (Page 19)

1. By using a megaphone or something that acts like one, such as your cupped hands.
2. It helps guide the sound waves into their ears.
3. Sound waves made by something vibrating travel through the air until they strike a hard surface. They are then reflected or thrown back through the air to you.
4. If sound waves are thrown back and forth several times, they become jumbled so that we cannot hear clearly. By using soft materials or materials with rough surfaces that do not reflect sound so well as those with hard, smooth surfaces.

Why are sounds different? (Pages 20-23)

Concepts

1. The highness or lowness of a sound depends on the speed of vibration. The faster a material vibrates, the higher the sound it produces.

   a) Thin materials can vibrate faster than thick ones.

   b) The more tightly a material is stretched, the faster it can vibrate.

   c) Short lengths of a material can vibrate faster than long ones.

2. The loudness of sound depends on how hard the object is vibrating, that is, how far back and forth it is moving. A material can be made to vibrate with more force by striking it harder.

Experiments

PAGE 20: To show why some sounds are high and others low.

MATERIALS: Chalk box, three rubber bands of the same length but of different widths, xylophone.

PAGE 21: To show why some sounds are high and others low.

MATERIALS: Three rubber bands of same length and width, three spools, pencil.

PAGES 22-23: To find out why some sounds are louder than others.

MATERIALS: See experiments for pages 9 and 11.

Information for the teacher

If any pupil has a toy xylophone, ask him to bring it to class for this problem. It is a good idea to have several of these xylophones, since there are different types. In some toy xylophones, the bars are all the same width. In others, the bars that make the higher tones are narrower as well as shorter than the ones that make the lower tones. It is this type that is needed for the experiments here.

The materials for the experiment on page 21 are easily put together. The spools are placed on the pencil and the bands wound around them to stretch the bands to a greater or less degree.

Procedure

Pupils will want to give their own ideas about why sounds are different from each other. Those who take music lessons will have ideas to contribute. After the discussion, in order to determine which ideas are correct, pupils should perform the experiment described on page 20, answer the questions, and read to the next experiment on page 21. Here the pupils will discover another reason why sounds are different. A xylophone or violin brought to school will help make this idea clear.

Have the pupils read to the end of the third paragraph on page 22. Then they should do the experiments mentioned in the next two paragraphs. To check their findings, the children should then read to the end of page 23. For additional activities, see *Things to Do*, page 31, Nos. 2, 4, and 5.

Questions (Page 23)

1. Thin string. Short string. Tight string.
2. One that vibrates slowly.
3. Tighten it.
4. By sending air past your vocal cords with less force so that they vibrate a shorter distance back and forth.

How do musical instruments make sounds? (Pages 24-29)

Concepts

All musical instruments produce sounds by making the air vibrate.

a) In stringed instruments, the sounds are made by vibration of the strings. Differences in length, thickness, and tightness of the strings make sounds that are high or low.

b) In the wind instruments, the sounds are produced by vibrations of a column of air inside the instrument. The length of the column of air can be changed to make high or low sounds.

Experiments and observations

Pages 24-27: To show how different sounds are made by musical instruments.

Materials: Violin, piano, xylophone, flute, saxophone.

Pages 27-28: To show how long and short columns of air make different sounds.

Materials: Eight test tubes (or small bottles or glasses) of same size, test-tube rack, water.

Information for the teacher

Pictures. Page 24. In the picture of this children's orchestra, the following instruments may be seen: *first two rows and ends of third,* violins; *center of third,* clarinets; *fourth row, left to right:* two trumpets, one french horn, one altonium, three saxophones, one violin; *back row, left to right:* tuba, two trombones, two baritones, drums, cymbals.

Page 25. Violin.

Page 26. Flute with keys.

Page 28. *Right,* trombone.

The following chart gives information about various musical instruments.

Instrument	*What Vibrates*	*How High and Low Sounds Are Produced*
Violin	Strings	Thin and thick strings can be shortened or lengthened
Piano	Strings	Hammers strike wires of different length, tightness, and thickness
Xylophone	Wooden bars	Hammers strike long and short bars
Flute	Column of air	Fingers or keys over holes in tube change length of column of air
Saxophone	Reed, column of air	Keys change length of column of air
Trombone	Lips, column of air	Part of instrument slides to change length of the air column; lips change
Tuba, Cornet, Bugle, or Trumpet	Lips, column of air	Valves change length of air column; lips change

Text. In a wind instrument, such as a flute, the length of the air column is changed by allowing air to escape or preventing air from escaping from the tube. When all the holes are closed, no air can escape and the column of air is longest and the notes lowest. Uncovering a hole allows the air to escape. Then the column of air is as long as the distance between the mouthpiece and the uncovered hole. The nearer to the mouthpiece the uncovered hole is, the shorter the air column and the higher the note. The holes may be covered by fingers or by *keys* that can be pressed to open or close. In other wind instruments, *valves* are pushed down to cut off the column of air and change its length.

The term *valve* is now generally used for the type of stop in which something like a piston is pushed down into the tube to change the length of the air column. Trumpets and bugles have valves. The term *key* refers to the type of stop that acts as a cover for the holes, as in a flute.

Procedure

Urge pupils to bring their musical instruments to the science class. Use each instrument as the text suggests to learn (1) how the instrument makes sounds, (2) how it can change sounds, (3) how sounds are controlled in the instrument, and (4) how the instrument is constructed to serve its purpose.

Have pupils show the instruments and encourage them to use the information they have acquired to understand the instruments. The children should read the problem to check their findings and to get additional information that they have not been able to discover. After all the instruments have been discussed, have the pupils put on the board a summarizing chart such as the one on this page of the *Guidebook.*

The experiment pictured on page 28 has many variations, such as hanging bottles containing different amounts of water from a support and experimenting to make a scale with them. See also *Things to Do,* Nos. 6, 7, and 8.

Questions (Page 29)

1. Violin, cello, bass viol, harp, guitar, piano, banjo, ukulele, etc.

2. Wires in a piano vary from long, thick wires on the left to short, thin wires on the right. When a piano key is struck, it makes a little hammer strike a wire which vibrates. Striking a long, thick wire makes a low sound. Striking a short, thin wire makes a high sound. The sound that each wire makes can be changed a little by tightening or loosening it.

3. Thick strings make lower sounds than thin strings; long strings make lower sounds than short strings; loose strings make lower sounds than tight strings.

4. No. The bars would all make the same sound.

5. He presses valves to change the length of the column of air; he makes his lips tight or loose.

6. No. Air blown through the reed makes the column of air in the saxophone vibrate.

How do you hear sounds? (Pages 29-30)

Concepts

1. We hear sounds because the sound waves travel to our ears and make the inner parts vibrate. Nerves carry the message of the vibrations to the brain, which interprets them into meanings.

2. It is very important to take good care of your ears.

Procedure

The picture on page 30 may be discussed to create an interest in how we hear. Then have the pupils read page 29 for a simple explanation and additional information. The pupils should then read and discuss the safety rules so that the reasons for each are thoroughly enough understood that they will become part of the pupil's behavior. See also *Things to Do*, page 31, No. 9.

Questions (Page 30)

1. It helps catch sound waves and guide them into your ear.

2. Because skin is stretched over the opening just as on the head of a drum.

3. If you always have trouble hearing, have a doctor look at your ears. A doctor can often help you hear more clearly; he can tell whether there is anything wrong with your ears.

4. To shut out some of the sound so that the eardrum will not be injured.

Questions to answer (Page 31)

1. List might include: voices—vocal cords; animals (dogs, cats, etc.)—vocal cords; automobile, bus, streetcar, etc.—motor; bells of various kinds—parts of a bell; leaves—wind; running water—whatever the water struck.

2. Yes. A child on one side of a closed door might make a sound that a child on the other side could not hear. The same sound repeated with the door ajar could be heard.

3. If nothing vibrates, no sound waves will be started.

4. If the parts of a bell have not been tightened or loosened or otherwise changed, the bell will vibrate at the same speed every time it is rung and so make the same sound each time.

5. Sound waves from the radio made the metal top vibrate and produce another sound. He could put a pad of some soft material between the radio and the table; then sound waves could not reach the top so easily.

6. By using different lengths and thicknesses of pins or by driving them in to different depths, or both.

Things to do (Page 31)

1. For crickets and katydids, see text, page 14. Most grasshoppers make no sound. One kind makes a *tsikk-tsikk* by rubbing a tooth-edged thigh against the front wing vein. The cracker locust, the Carolina locust, and a few others make a crackling sound with their wings when they fly. Cicadas have a drumhead at the base of their hind wings. Muscles inside their bodies set them in vibration. A large air cavity in the abdomen acts as the drum. See Bibliography on page 108 of the *Guidebook*.

2. The short reeds make the high sounds; the long ones, the low sounds.

3. All letters are made by special placement of the lips and tongue. However, some are voiced (use vocal cords); others are voiceless. All vowels combine lips and tongue with voice. *B* is voiced, while *p* is not. *S* or a soft *c* is not voiced, while *z* is. *D* is voiced, while *t* is voiceless, etc.

4-9. Individual or class activities.

10. A giraffe has no vocal cords. It can only make a kind of snort.

UNIT 2. *Why Does the Weather Change?*

Purpose and scope

There are many things about the study of weather that are interesting to girls and boys. It is not the intention of this unit to give a large amount of technical information. It is rather the purpose to broaden the interest, to build on previous knowledge of how water evaporates and condenses, and to use this knowledge to understand some of the simple phases of weather changes. Pupils at this level cannot forecast weather, but they can begin to understand some of the things that scientists need to know in order to forecast. They can also develop an appreciation of the work and worth of the Weather Bureau.

In this unit it is important to help pupils connect the various science principles concerning air and the various changes in it with the final problems in the unit that are concerned with weather changes and the forecasting of weather changes.

Science background

Look and Learn: Unit 3, Days and Days

All Around Us: Unit 3, Sun, Wind, and Weather

Discovering Our World, Book One: Unit 2, Why Do All Living Things Need Air and Water? Unit 4, Why Do We Have Days and Nights?

Discovering Our World, Book Two: Unit 2, What Makes Things Move? Unit 4, How Do Heating and Cooling Change Materials?

General concepts

1. Weather is the condition of the air around us. Changes in weather are changes in the air.
2. The air is not warmed equally at all places by the sun.
3. Clouds covering the sun may change the temperature of the air.
4. Some parts of the world are always warmer or colder than other parts.
5. Winds from colder or warmer places change the temperature.
6. Wind is moving air.
7. Gravity makes the air move.
8. Water comes out of the air as clouds, rain, snow, sleet, hail, fog, frost, and dew.
9. Weather is forecast each day by the Weather Bureau.
10. Weather reports help us prevent damage and destruction.

Introducing the unit (Page 33)

The unit may be started by asking the pupils to describe the kinds of weather they have been experiencing during the past week. Then have them read page 33.

What do we mean by weather? (Pages 34-36)

Concepts

Weather is the condition of the air around the earth. Changes in the weather are changes in the air.

a) The air may be clear or cloudy.

b) The air may be still, or it may be moving slowly or swiftly.

c) The air may be hot, cold, cool, or warm.

d) The air may be dry or moist.

Observations

PAGE 34: To find out what weather is.

MATERIALS: Weather reports from newspapers and radio broadcasts.

PAGE 36: To observe weather changes over a period of weeks and to keep a record of these changes.

MATERIALS: Thermometer, daily weather reports from newspapers and radio.

Information for the teacher

PICTURES. PAGE 34. *Top*, fog. *Bottom*, snow. PAGE 35. *Top*, partly cloudy. *Bottom*, rain.

Procedure

As suggested in the text, have the children list the words that they have been using to describe the weather. The discussion should lead to an understanding that weather is the condition of the air around the earth. Have the class read pages 34-36. The record of the weather entered on a chart such as the one described on page 36 is interesting to keep and use as the unit progresses.

Questions (Page 36)

1. Answers will vary.
2. Answers should include changes in sky condition, temperature, moisture, and wind.
3. No. Weather is the condition of the air around the earth.
4. No. He omitted the condition of the sky, the moisture fall, and also the direction of the wind.

Why does the air get warmer or cooler? (Pages 36-39)

Concepts

1. The air is not warmed equally at all places by the sun.

   a) The sun's rays pass through the air without heating it much.

   b) The soil, rocks, and water of the earth's surface are heated by the sun's rays; then the earth's surface warms the air above it.

   c) Different kinds of materials on the earth's surface are warmed differently by the sun.

   d) The air is warmest where the earth is heated most.

2. The air is usually warmer in the daytime than at night.
3. The air is warmer in summer than in winter.
4. Clouds covering the sun may change the temperature of the air.
5. Some parts of the world are always warmer or colder than other parts.
6. Winds from colder or warmer places change the temperature.

   a) Wind from the south is usually warm.

   b) Wind from the north is usually cold.

Experiments and observations

PAGE 36: To observe how the temperature changes during the day.

MATERIAL: Thermometer.

PAGE 37: To show that the sun's rays heat some materials more than others.

MATERIALS: Two small glass jars that are just alike, candle or dull black paint, thermometer, water.

Information for the teacher

PICTURE. PAGE 38. The sun's rays pass through the transparent glass of the greenhouse. The light rays strike the soil and cannot pass through it. They are absorbed by the dark, opaque soil. The soil is warmed because the energy of the sun's rays is changed to heat. The soil gives off some of its heat to the air above it, thus warming the air in the greenhouse.

TEXT. In the experiment with the glass jars, the radiant energy from the sun is changed to heat energy when it strikes a material that absorbs it. Transparent materials allow sunlight to pass through them; those that are not transparent either reflect the sunlight or absorb it. No material is so perfectly transparent or so perfectly reflecting that it will absorb no sunlight whatever. Pure white reflects most of the sunlight; pure black absorbs most of it. Thus black or dark opaque objects will become warmer in sunlight than white or transparent ones. In the jar that is painted black, the water will be warmed more than that in the clear glass jar.

Procedure

The temperature changes taken from the chart and those taken at various times of day will help pupils realize the wide changes that take place. The experiments described in this problem will help them understand why these changes occur. The pupils can feel the difference between the temperature of the window glass and that of the window sill when the sun shines. One is transparent and lets the sun's rays through; the other absorbs them and becomes hot. Have the pupils do the experiments and then read pages 36-39 to obtain additional concepts.

This problem indicates several factors that are responsible for changes in the temperature. The pupils should make a list of these factors, indicating how they may bring about changes in temperature.

Questions (Page 39)

1. Materials through which the rays cannot pass. Clear materials that the rays will pass through.

2. *Much:* soil, rocks, buildings, people, metal, etc. *Little:* air, glass, small quantities of water, etc.

3. The sun's rays that strike the earth are changed to heat. The earth gives up some of this heat to the air above it.

4. The air becomes warmer during the day when the sun is shining on our side of the earth. Then it becomes cooler at night when the sun is shining on the other side of the earth.

5. Over the land. The sun warms the land more than the water.

6. Clouds shade the earth, keeping some of the sun's rays from reaching it. The earth and the air above it become cooler. Also, a cool breeze blows over the land.

7. Clouds shade the earth. The earth becomes warmer in the day and cooler at night. More hours of sunlight make it warmer in summer. The wind blows from warmer or cooler places.

What makes the wind blow? (Pages 40-43)

Concepts

1. Wind is moving air.
2. Gravity is the force that makes the air move.
    - *a*) Air has weight.
    - *b*) Cold air weighs more than warm air.
    - *c*) Cold air sinks and pushes warm air up.
3. The air moves (wind blows) because cold air is pressing down and sideways and pushing against warm air, making it move.

Experiment

PAGE 41: To show how air moves in a room.

MATERIALS: Strips of paper or cloth, window pole (or other long pole), window that opens at the top and bottom.

Information for the teacher

PICTURES. PAGE 40. The picture shows what a strong wind a hurricane is. In a hurricane, the wind moves more than 75 miles an hour.

PAGE 41. How to perform the experiment.

PAGE 42. The arrows in the picture show which way the wind is moving.

Procedure

Doing the experiment pictured on page 41 is an interesting way to begin the study of this problem. Let the pupils use their observations and the text to explain how air moves in the schoolroom. Have the children list the things that happen to make the air move. Then the pupils are ready to understand how a like situation outdoors causes the air to move and a wind to blow.

If the pupils have studied the unit on heat in *Discovering Our World, Book Two*, they should be asked to recall the convection-box experiment (page 114 of *Book Two*). Or the experiment may be repeated here if the pupils do not recall it.

The picture on page 42 may be used to summarize what pupils have learned by asking them to tell as completely as they can what is happening in the picture and why it happens.

Questions (Page 43)

1. (*b*), (*e*).

2. The greater the difference in temperature between two places, the faster the air will move toward the warmer place.

3. During the day, the air over the land is warmer. It is pushed up by the cooler air from the water. So the wind blows from the water to the land. At night, the land cools off more quickly than the water does. Then the air over the water is warmer. So the wind blows from the land to the water.

4. The fire makes the air over the forest warmer so that the cooler air around the forest pushes in, causing a wind.

Why is the sky clear or cloudy? (Pages 43-47)

Concepts

1. Water is always evaporating from oceans, lakes, rivers, etc.

2. Warm air can hold more water vapor than cold air.

3. When warm, moist air is cooled, the water vapor condenses.

4. When the condensed water vapor stays in the air, it forms clouds of different kinds.

5. Fog is a cloud that has formed near the earth's surface.

Experiment

PAGE 44: To observe condensation of water vapor from the air.

MATERIALS: Metal cup, chipped ice.

Information for the teacher

PICTURES. PAGE 44. Water is evaporating from the surface of the lake or stream. The air above the water is cool in the early morning. So the water coming from the lake or stream condenses to form a mist.

PAGE 46. *Left*, cumulus. *Right*, stratus. See the Bibliography for books about clouds.

Procedure

This problem may be introduced by taking pupils outdoors to look at the sky and to watch the clouds. They may see clouds move, clouds disappear, and new clouds appear. The children have had experiences with evaporation and condensation. Using these experiences and the knowledge they have gained about winds and air temperatures, let the pupils try to decide what conditions can cause clouds and what conditions can cause them to disappear. Then these pages may be read and discussed. The pictures in the text can be used by pupils to help identify different kinds of clouds.

Questions (Page 47)

1. It evaporates from oceans, lakes, rivers, wet soil, wet plants, etc.

2. Water evaporates into the air. If this air is cooled, it cannot hold so much water vapor. So the water vapor condenses into tiny drops, forming a cloud.

3. The sun warms the earth, which warms the air. The air can then hold more water vapor. So the water in the fog evaporates, and the fog disappears.

4. (*a*) No. There is always water vapor in the air, but on a clear day the air is warm enough to hold all that there is. (*b*) No. You can never see water vapor because it is an invisible gas that mixes with other gases in the air. On a cloudy day, you see drops of liquid

water or crystals of ice. (*c*) Yes. But the air must be cooled enough so that it can no longer hold all the water vapor in it. The water vapor condenses and can be seen.

5. The air high above the earth is usually cooler, and so it holds less water vapor than air lower down. The plane is cooled in the upper air. When it comes down, water vapor in the warmer air may condense on the cool plane. If the temperature is below freezing, ice will form.

6. Water vapor in the warm air condensed on the cold pipe.

How does water come out of the air? (Pages 48-49)

Concepts

1. When the tiny droplets of water in clouds join together and fall, they make rain.
2. Sometimes the water vapor freezes and makes snow.
3. Sometimes raindrops freeze and make sleet or hail.
4. Dew is formed from water vapor that has condensed near the ground on soil, plants, or buildings.
5. Frost is formed from water vapor near the ground that has frozen instead of condensing to water.

Information for the teacher

PICTURE. PAGE 48. Snowflakes. Snowflakes are usually six-sided, occasionally three-sided.

Procedure

This problem is a direct outgrowth of what was learned in the previous one. It may be introduced by a question such as "What have we already learned that will help us solve the question at the top of page 48?" After the discussion, have the pupils read pages 48-49 to check their answers.

Questions (Page 49)

1. It must be cooled until it can no longer hold all the water vapor in it.

2. There would be no water vapor in the air. So water vapor could not condense to form clouds, fog, rain, snow, sleet, hail, dew, or frost.

3. See the first complete paragraph on page 45. Just as cooling the cloud from a teakettle causes larger drops to form, so a cloud in the sky that is cooled will condense into large enough drops to fall in the form of rain.

4. No. Snow is formed directly from water vapor when the temperature is near freezing or below. Sleet is formed from raindrops, which freeze as they fall.

5. (*a*) Yes. Raindrops would not be pulled down to the earth; nor would cold air move and change the temperature, causing water vapor to condense. (*b*) Yes. It may evaporate into the air, condense, and then fall as rain, snow, etc. (*c*) Yes. They are made of layers of frozen rain. (*d*) No. Frost is formed directly from water vapor. The water vapor freezes without changing to water first. (*e*) No. They are formed when warm air touches a cool object and water vapor condenses directly on that object.

What does the weatherman do? (Pages 50-55)

Concepts

1. Weather is forecast each day by the Weather Bureau.
2. Weather maps are made every day.
3. A weather map shows pressure of the air, direction and speed of wind, amount of water coming out of the air, and temperature of the air.
4. A weather forecaster can predict the next day's weather by studying the weather map.

Information for the teacher

PICTURES. PAGE 50. Part of the program of the Air Forces' Air Weather Service for the study of thunderstorms and what happens inside them.

PAGE 51. *Left*, recording barometer, or barograph. *Right*, a tipping-bucket rain gauge on the roof of the Whitehall Building, New York City. It is connected electrically with a recorder in the Weather Bureau. The rain caught in the funnel flows into a partitioned bucket, which tips when a hundredth of an inch of rain has fallen. Each tip is recorded.

Page 52. *Left*, weather vane, or wind vane, and anemometer. The weather vane points in the direction from which the wind is coming. The anemometer has the three cup-shaped devices, which catch the wind. The harder the wind blows, the faster they spin. *Right*. The balloon carrying a radio is known as a *radiosonde*.

Page 53. A card of directions for returning the instrument is attached to each one sent up. One dollar is paid for each one returned.

Page 54. A *cold front* is a boundary line between a mass of cold air and a mass of warmer air under which the colder air pushes like a wedge, usually moving southward or eastward. A *warm front* is the boundary between a mass of warm air and a mass or wedge of cold air over which the warm air is forced, usually moving northward or eastward.

Procedure

The discussion here centers around how scientists are able to forecast the weather. Pupils may bring sample weather reports from the local paper and try to decide what information the forecaster had to have in order to make this report. Then, by reading the text and studying the pictures, they should find out how scientists get this information.

The weather map on page 54 is considerably simplified. It should be used just to call attention to what may be shown on such a map.

If pupils decide to keep records of how often the weather forecasts are accurate over a period of time, the cautions given on page 54 should by all means be observed.

Questions (Page 55)

1. Temperature and pressure of the air, direction and speed of the wind, amount of water coming out of the air.

2. Thermometer, barometer, rain gauge, weather vane, instrument that measures the speed of the wind, balloon with radio attached.

3. By making daily reports of weather at the stations and sending them to cities where weather maps for the whole country are drawn and forecasts are made.

4. Where large masses of warm and cold air are and how fast and in what direction these masses are moving; whether the air is warm or cold, moist or dry; what is happening to the weather all over the country.

5. It may be true for the large area for which it is made but not for some small part of that area. Also, weather may change too quickly to be forecast or may not change as conditions indicate that it will.

How do weather forecasts help us? (Pages 55-57)

Concept

Weather reports help us prevent damage and destruction.

Information for the teacher

Pictures. Page 55. Any of the large almanacs will give the other storm warnings. These will be especially interesting to children living along the coasts or near the large inland lakes.

Page 56. Pilot and co-pilot going over the weather map with the dispatcher before taking off.

Page 57. Some of these heaters burn oil. In some places, wood fires are used instead.

Procedure

This problem should be made as real to pupils as possible by having them find out which people in their own community use weather forecasts. After the discussion, have them read pages 55-57 to learn how people in other communities use weather forecasts.

Questions (Page 57)

1. They help us know how to dress, how much to protect or warm our homes, when to

prepare for storms, frosts, or floods, and how to make our plans fit the weather. They also help us by helping fuel dealers, farmers, shippers, steamship companies, air lines, foresters, etc.

2. They learn how to make nearly correct forecasts so that we can be prepared for changes in the weather.

3. They need to know the weather high above the earth because it is often different from the weather on the ground. They need more frequent reports because a sudden change in weather can be a great danger to flying.

Questions to answer (Page 58)

1. Temperature, moisture, speed and direction of wind.

2. It evaporates and changes to water vapor.

3. At night, the earth and the air above it usually become cooler. Cooler air cannot hold so much water vapor. So some of it may condense into fog. In the daytime, the air is likely to become warmer. It can hold more water vapor.

4. Some of the water vapor in the warm air may condense into a cloud; or rain, snow, etc., may fall.

5. It pulls down harder on cold air than on warm air. Cold air forces warm air up, and a wind starts to blow. Wind may bring changes in the weather. Also, gravity makes rain, snow, etc., fall to the ground.

6. On a cloudy day people use more electric current for lights than they do on a clear day. The electric companies must be ready to supply extra current.

7. See page 40 of the text. Twelve cubic feet of air weigh about one pound. Multiply the length of the room by the width by the height and divide by 12.

8. Air in a warm room contains much water vapor. When this warm air touches the cold pitcher, the air is cooled. Cool air cannot hold so much water vapor. So some of the vapor condenses into liquid water on the outside of the pitcher.

9. PAGE 58. *Left*, hailstones. Air currents carried raindrops up and down many times through layers of cold and warm air. Each time they went through cold air, a layer of ice formed on them. More and more ice was added until the balls finally fell to the ground. *Right*, sleet. As rain fell to the ground, it passed through some air cold enough to make it freeze.

PAGE 59. *Left*, dew. The leaves of the plant became cooler than the air around them. Some of the water vapor in the air condensed on the leaves. *Right*, frost. The air cooled below freezing. Water vapor in the air froze on the leaves.

Things to do (Pages 58-59)

1. Most newspapers give a brief forecast that includes sky condition, moisture fall, if any, temperature, and wind direction and speed. Some newspapers also give a second, more detailed forecast and report including maps, tables, weather in and around other cities or areas, etc.

2. Prevailing winds vary from winter to summer in different parts of the country. The table below shows the prevailing winds in various parts of the country. (Information for the table is from T. A. Blair, *Climatology*, pages 141-142.)

Season	*Central U. S.*	*Atlantic States and Eastern Canada*	*Pacific States and Western Canada*	*Mexico and Florida*	*Gulf Coast*
Winter	Northwest	West or northwest	Southeast, south, or southwest	Northeast	From the interior
Summer	South or southwest	South or southwest	Northwest	East or southeast	East or southeast

3. Be sure to set the can above the "ground splash." Newspaper weather summaries and almanacs can be used to check results.

4. Besides looking up thermometer, barometer, rain gauge, and weather vane, students may wish to know the names of other instruments. Either a *psychrometer* or a *hair hygrometer* (for when the temperature is very low) is used to tell how much water vapor is in the air. An *anemometer* tells the speed of the wind. Balloons sent up to find winds aloft are called *pilot balloons* or, if used at airports to find the altitude of the clouds, *ceiling balloons*. A larger balloon with a radio attached is a *radiosonde*. Also used are instruments that make records such as a *recording thermometer*, *maximum* and *minimum thermometers*, a *barograph*, *sunshine recorder*, *sounding balloon*, and *triple register* (connected to wind vane and anemometer).

5. Individual or group activity.

6. Although many maps will be more complicated, all will include such markings as are seen on the one on page 54 together with the figures and symbols that describe weather conditions at each reporting station. Most maps will have a key to these symbols and an explanation of other markings.

7. "Any Truth to Weather Lore," *Science Digest* for July 1946, discusses many old sayings in terms of scientific facts. The article is condensed from the book *Science in a Changing World* by Cable, Getchell, and Kadesch, Prentice-Hall, 1946.

8. Groups may visit either city weather bureaus or reporting stations at airports.

UNIT 3. *How Is the Earth's Surface Changed?*

Purpose and scope

The aim of this unit, after presenting a bird's-eye view of the earth's surface, is to show the elementary forces that have changed this surface through the ages and are changing it today. The pupils should find out that there are two kinds of changes, the building up and the tearing down, and that over a long period of time these balance each other. The time element in this unit is important—the length of time it takes to wear away surface and the length of time necessary to rebuild worn-out and eroded soils.

Newspapers and magazines often contain articles on flood control, prevention of erosion, "dust-bowl" problems, and kindred topics, to say nothing of rather frequent stories of floods, earthquakes, landslides, and volcanic eruptions. The alert teacher will find an abundance of material to enrich her classroom presentation and to post on the bulletin board.

Much of the material in this unit will be of general interest to pupils; the problem on soil conservation is especially important. The entire unit will be more meaningful if it is made concrete by observations that pupils make in their own localities. Many of the pupils will probably be interested in collecting and studying rocks.

Science background

All Around Us: Unit 3, Sun, Wind, and Weather

How Do We Know?: Unit 2, Land and Water

Discovering Our World, Book Two: Unit 1, How Do Living Things Help and Harm Each Other? Unit 2, What Makes Things Move? Unit 4, How Do Heating and Cooling Change Materials? Unit 5, What Are Things Made Of? Unit 9, How Can You Make a Garden?

Discovering Our World, Book Three: Unit 2, How Does the Weather Change?

General concepts

1. The earth's surface is made up of water and land in many different forms.
2. The earth's surface is always changing.
3. The land is made up of either rock or soil.
4. Many forces are at work breaking up rocks and wearing them away.
5. Water changes the earth's surface.
6. Wind changes the earth's surface.
7. Glaciers change the earth's surface.
8. Volcanoes change the earth's surface.
9. Mountain ranges are formed when pressure from unknown causes pushes up part of the earth's surface.
10. The soil must be conserved.

Introducing the Unit (Pages 61-62)

Information for the teacher

Pictures. Page 60. A scene in Monument Valley, Utah.

Page 61. A natural bridge, such as found in Natural Bridges National Monument, Utah.

Procedure

Presenting a motion picture showing changes in the earth's surface is a very interesting way to introduce this unit, if such a picture is available. This is particularly true since motion pictures make these concepts more real. Or, if this is not possible, pupils may discuss these questions: "How do you think the surface of the earth in our region has changed?" "How long do you think it takes such changes to happen?" Then they may read pages 61-62.

See page 119 of the *Guidebook* for possible sources for motion pictures.

What is the earth's surface made of? (Pages 62-66)

Concepts

1. The earth's surface is made up of water and land in many different forms.
2. The earth's surface is always changing.
3. The land is made up of either rock or soil.
   - *a*) There is always rock under the soil.
   - *b*) There are different kinds of rocks that have been made in different ways.
   - *c*) Soil is made from rock that has been broken up into fine bits, with decayed plant and animal material added to it.

Experiment

Page 66: To find out what soil is made of.

Materials: Tall glass jar or bottle, soil, water.

Information for the teacher

An excellent reference for the teacher, including many illustrations that will be useful to the pupils, is *The Rock Book* by Carroll Lane Fenton and Mildred Adams Fenton. See Bibliography for other helpful books about rocks and soil.

Procedure

An assignment to bring pictures to show how the earth's surface is different in different places might be made to lead into the first problem. Suggest also that pupils try to find different kinds of rocks. Let them show the pictures they have brought and also examine those in this part of the unit to tell what the earth's surface is made of. After this discussion and observation, the pupils may read as far as the second half of page 63 to find additional information.

The rocks brought by the pupils should then be examined. The paragraphs following on pages 63 to 66 will then help them decide what kinds of rocks they have found. It will help them tell how the rocks are alike and how they are different from each other. The pupils may also be able to tell what may happen to each kind of rock. It is important in this connection to see how rocks and soils are related.

The study of the various kinds of rocks should be followed by the experiment about soil described on page 66 so that the pupils will come to understand (1) what soil is made of and (2) how soil can change.

Questions (Page 66)

1. (*a*) False. (*b*) True.

2. *Sandstone* is made of tiny bits of sand that have settled to the bottom of the ocean. Water and layers of sand on top press down with great force until these bits are pressed together into rock. *Limestone* is made of the bones of fishes and shells of other sea animals pressed together at the bottom of the ocean by the weight of other layers and water on top. *Shale* is made of mud pressed into rock at the bottom of the ocean in the same way.

3. *Marble* is made from limestone that was heated and then crushed with great force, probably by layers of rock on top. *Slate* is made from shale that was heated and crushed. *Granite* is an igneous rock, that is, a mixture of minerals that was melted by great heat inside the earth. The melted rock was forced upward toward the surface, where it cooled.

4. No. Soil is made of sand, clay, and decayed plant and animal materials. The sand is made from tiny bits of rock and the clay from rock that has been ground to powder; but the decayed plant and animal material is from plants and animals that have died.

5. Great changes have been made in the earth's surface since the earth was just a ball of rock.

How are rocks broken up? (Pages 67-69)

Concepts

Many forces are at work breaking up rocks and wearing them away.

- *a*) Heating and cooling breaks up rocks.
- *b*) Freezing water breaks up rocks.
- *c*) Plant roots break up rocks.

Experiments

PAGE 67: To show that heating and cooling may cause things to crack.

MATERIALS: Thick glass or bottle, cold water, hot water.

PAGE 68: To observe that freezing water expands and exerts a force.

MATERIALS: Bottle, cork, wire, water, means of freezing water.

Information for the teacher

PICTURES. PAGE 67. Piles of broken rock that have accumulated at the bases of cliffs or steep slopes are called *talus*. They are also known as talus slopes. The sizes of the pieces of rock vary from pieces as small as dust to large blocks. They are usually broken from the cliff or mountain sides by the steady freezing and thawing of the rock and finally by the pull of gravity. Large pieces of rock falling onto the pile and rolling over it break up the talus into smaller and smaller pieces. This is a picture of the talus slope at the base of the east face of Long's Peak, Colorado. The picture is taken across Chasm Lake, which is at an altitude of 12,000 feet.

PAGE 68. Alternate contracting and expanding caused by changes in the temperature have cracked the rock. Water will get into the cracks, and the freezing of the water will widen the cracks until pieces finally break off from the rock.

PAGE 69. As the roots of these trees grow, they will have enough force to break the rock. In this way, they will gradually help break down the cliff.

Procedure

Pupils may examine the rocks they have brought in to try to see how they might become broken up to make soil. The experiments described on pages 67 and 68 will help them see how temperature changes may cause rocks to break. Pages 67-69 may then be read for additional information.

Questions (Page 69)

1. Heating makes things expand; cooling makes them contract. When the sun shines on a rock, the outside expands faster than the

inside; and so the rock cracks. At night, the outside cools and contracts faster than the inside. So the cracks become larger. After much heating and cooling, the cracks become so large that pieces begin to break off.

2. Water expands when it freezes. If rain seeps into cracks in a rock and then freezes, the force of the expanding water makes the cracks larger.

3. If the seed falls into a crack where there is soil, it sprouts and starts to grow. The roots can reach into very tiny cracks. Growing roots have enough force to split rocks.

4. Heating and cooling have made many cracks. Ice, rain, and melting snow have gone into the cracks and are breaking off pieces.

How does water change the earth's surface? (Pages 70-74)

Concepts

1. Water that falls as rain or snow carries soil from high to low places as it runs off.
2. The water in streams has force and can carry soil and rocks along with it.
3. Water washes soil away from some places and piles it up in others.
4. Moving water grinds rocks together, breaking them and wearing them off.
5. The action of the rocks as they are moved along by water digs the beds of streams deeper.
6. Water helps make caves in the earth.

Experiment

PAGE 71: To observe soil moved by water.

MATERIALS: Sand table or sandbox, bucket of water.

Information for the teacher

PICTURES. PAGE 70. Some of the soil is carried downstream; some is deposited at the edges of the stream as shown in the picture; some may be deposited on the banks of the stream farther down if the stream overflows.

PAGE 72. The valley on the right is older. The water has worn a wide path through the valley and slowed down so that soil is deposited at the sides of the stream, making the flood plain or flat valley bottom. An old valley is U-shaped.

PAGE 74. Carlsbad Caverns, New Mexico. The stone "icicles" that hang from the ceiling of the cave are called *stalactites.* Those that come up from the floor are *stalagmites. Columns* are formed when a stalactite and a stalagmite join. They are all formed by the redepositing of material that has been dissolved by ground water.

TEXT. An excellent reference for the teacher for this and subsequent problems of this unit is *Down to Earth* by Croneis and Krumbein. (See Bibliography.) It has many excellent pictures that will be useful to the pupils.

Procedure

This problem should be presented by drawing on as many first-hand experiences as possible, such as a field trip to observe the effects of streams on the earth's surface or the experiences of pupils who have seen floods or visited caves. Use the pictures in the text and others collected from papers and magazines. After the discussion of experiences and the observation of pictures, have the pupils read the problem.

Questions (Page 74)

1. The rain or melting snow washes soil into the streams.

2. The water rolls them over and over and rubs them together until they are worn round and smooth.

3. It moves soil from one place to another. It wears down and breaks up rocks.

4. Water from rain or melting snow breaks off pieces of rock and carries them into streams and rivers. The moving water wears down the rock and grinds it into tiny bits. These tiny pieces may be carried down until the rivers empty into the ocean.

5. Stones are heavier than bits of soil. The fast-moving water carries away the soil but not the larger stones, which settle to the bottom.

6. By water and chemical change. (See pages 73-74 of the text.)

How does wind change the earth's surface? (Pages 75-77)

Concepts

1. Wind picks up dry sand or soil from some places and piles it up in others.
2. Wind wears away rock by blowing sand against it.

Experiments

Page 76: To see how sand dunes are made.

Materials: Sand table or sandbox, small board, sand, fan.

Page 76: To show how wind-blown sand can cause erosion.

Materials: Sand, magnifying glass or microscope.

Information for the teacher

Pictures. Page 75. Sand dunes near Yuma, Arizona.

Page 77. The Bad Lands of South Dakota.

Text. The dust storms in western United States illustrate the subject matter here. Sandblasting machines for cleaning stone and taking the paint off automobiles are excellent illustrations of the cutting power of wind-driven sand. Pupils may write for information about places in their state that have unusual surface forms such as those pictured in this problem. The state guides of the *American Guide Series*, now available for most states, are excellent sources of information about the places of interest in your region.

Procedure

This problem may be introduced by a study of the picture of sand dunes on page 75. Then have the class do the experiments on page 76. The pupils should read the text to check their findings and discuss the photographs on pages 76 and 77.

Questions (Page 77)

1. It carries soil and sand from one place to another. It helps the sand wear down and break up rocks.
2. Wind picks up sand and carries it along until it comes to a hill, plants, or some other obstruction. The sand is piled up here. Or if the wind slows down, the sand falls to the ground. As more and more sand falls in the same place, a dune is formed.
3. Wearing away of the earth's surface.
4. (*a*) Both. Water from rain, melting snow, streams, and rivers. Wind picks it up and carries it along. (*b*) Only water. Water can carry larger pieces of rock, but wind can carry only sand and soil. (*c*) Both. Water breaks off pieces of rock and grinds them down as it carries them along, while wind blows sand, which cuts and grinds against the rocks. (*d*) Only wind. Water flows downhill, carrying sand and soil to lower places.

How has ice changed the earth's surface? (Pages 78-80)

Concepts

1. A glacier is a great sheet of ice that is moving over the land.
2. Glaciers scoop up great loads of rock and soil as they move along.
3. When the glacier melts, the rock and soil are dropped, forming hills.
4. Some of the scooped-out places made by the glacier are left as valleys; others become filled with water to form lakes.

Information for the teacher

Picture. Page 80. The Great Terminal Moraine at Moraine Lake in Canada. It took hundreds of thousands of years of glacial movement to make this huge pile of rock. Moraines deposited at the ends of glaciers are known as *terminal moraines*. Those left at the sides are *lateral moraines*. Sometimes material is dropped under a glacier. This material forms a *ground moraine*. Not all terminal and lateral moraines will appear as piles of bare rocks as the one in this picture does. In the regions where the moraines were deposited many years ago and glacial action has stopped, they have become covered with soil and vegetation so that they appear as low hills covered with plants.

Text. Just why glaciers "flow" is somewhat of a mystery to scientists. They think that part of the reason is found in the terrific pressure of the ice at the center of the glacier. This pressure could force the ice to flow out in all directions from the center. An excellent article on glaciers may be found in *Natural History Magazine* for October 1947.

Procedure

The picture of the glacier and the map of the ice sheet on pages 78-79 may be used as the basis of discussion. After the discussion, have the pupils read pages 78-80. The following questions may be used as a guide: "What makes the glacier move forward and then back?" "How does a glacier change the earth's surface?" "Have glaciers changed the earth's surface where we live?"

If you live in a glaciated area, it would be very interesting to identify for the children certain land forms in your vicinity that are the result of glaciation. A request to the geology department of the state university or the state geological survey will almost certainly bring detailed information on this subject.

It would also be interesting to collect stones that were brought down by the glacier. A nearby stone quarry or outcropping of rock will show what the bedrock of the region is. Comparing this rock with the rocks that have been collected will show that the rocks must have come from some other region, since the bedrock of your locality is of a different kind. Rocks that were deposited by glaciers are usually rounded. They may show lines made when other rocks rubbed against them.

Questions (Page 80)

1. South Pole, Greenland, Rocky Mountains.
2. As a sheet of ice moves over the land, it pushes off the tops of hills, scoops and scrapes out great holes, picks up soil and rocks, and carries them along with it.
3. Glaciers move very slowly, only a few feet a year.
4. Melting water filled low places that had been scooped out, making lakes. As the glaciers melted back, the rocks and soil that had been dragged along were left behind, making hills.
5. A ridge of rocks left at the sides and end of a glacier as it melted back.

How do volcanoes build up the earth's surface? (Pages 81-84)

Concepts

1. Volcanoes pour melted rock over part of the earth's surface.
2. They blow out ash that may be spread by the winds.
3. They make mountains by building themselves up with lava and ash.
4. Very rich soil is made from lava and volcanic ash.

Information for the teacher

Pictures. Pages 82-83. Paricutin began to erupt in February 1943. There are many well-illustrated articles in recent periodicals that describe the course of events since that day. Three excellent articles are: "Paricutin Is Born," *Natural History Magazine*, October 1943; "Paricutin Comes of Age," *Natural History Magazine*, October 1944; "Paricutin, the Cornfield that Grew a Volcano," *National Geographic Magazine*, February 1944.

Page 84. Crater Lake is six miles in diameter and 2000 feet deep.

Procedure

To introduce this problem, have the pupils read the story of Paricutin on page 81. The pictures on pages 82-83 should also be discussed. Then the pupils may read and discuss the rest of the problem.

Questions (Page 84)

1. Points to be brought out: (1) Some places inside the earth are hot enough to melt rock.

(2) The liquefied rock and the steam and gases that are formed with it are lighter than the solid rock around them and so are forced up. (3) They are pushed up with great force; if there is a weak spot in the surface, they pour out or burst out in an explosion (erupt).

2. As lava, hot rocks, steam, mud, and ash pour out, they pile up around the hole, making a mountain. Dry ash is carried by the wind for many miles before it settles in layers.

3. Steam condenses to water and makes mud out of the dry ash.

4. Yes. It was melted by great heat inside the earth, then forced up to the surface, where it slowly cooled. (See *igneous rock*, page 65 of the text.)

5. Rock blown to bits by the explosion of a volcano.

6. By its cone with a crater in the top; by the kind of rock and soil it is made of.

7. When lava flows out on the land, it slowly cools and becomes hard. This hard rock is crumbled by rain, sun, plants, and wind and becomes part of the soil.

How are mountains made? (Pages 85-87)

Concept

Mountain ranges are formed when pressure from unknown causes pushes up part of the earth's surface.

Experiment

Page 85: To see how mountains may be formed.

Material: Sheet of paper.

Procedure

Have the children read and discuss the first three paragraphs of this problem and do the experiment pictured at the bottom of page 85 to clarify the idea of how the forces operate. Study the pictures of mountains for the purpose of contrasting new and old mountains. Then have the children read the entire problem for additional information.

Questions (Page 87)

1. High on mountains, they have found layers of sedimentary rock originally formed deep in the ocean. These layers are often bent up like a ridge; so some great force must have pushed sidewise on them.

2. Young mountains are still sharp and jagged, while old mountains have been worn down until they are smooth and rounded. (See the pictures on pages 86 and 87.)

3. If they know when the plant or animal lived, they can tell how long ago the rocks were formed. From this, the scientists can tell the age of the mountains in which the rocks are found.

How can we conserve the soil? (Pages 87-92)

Concepts

1. The soil must be conserved.
2. Living things could not stay alive without soil.
3. It takes 500 to 1000 years to make one inch of good soil.
4. The soil can be conserved in these ways:
   a) Crops are planted across the slopes of a hill instead of up and down.
   b) Grass, trees, or other plants are planted to prevent soil from blowing or washing away.

Experiment

Page 91: To see that plants help hold the soil.

Materials: Slope covered with plants, slope with no plants growing on it, bucket, water.

Information for the teacher

Pictures. Page 88. Serious erosion of a steep bank or hillside.

Page 89. A dust storm approaching a small town, which was totally dark for an hour and a half while the storm passed over it.

Page 90. This picture shows two methods of preventing erosion. One way is plowing across or around the slope of the hill instead of up and down. This is called *contour plowing* because the plow follows the contours of the land. The other method is *strip cropping*. A crop that holds the water, such as grass, is alternated with another crop that does not hold the water so well, such as corn. When the water runs off this latter section of the hill, it is caught by the strip of grass below.

Page 91. The vine used here to bind the soil is called *Kudzu vine*. Since it grows rapidly and has excellent soil-binding and protecting qualities, it is being widely used in soil reclamation projects. The two pictures show the same gully three months after planting and again three and one-half years later.

Text. Much material on the necessity for soil conservation and the methods of carrying it out is available to the teacher. State departments of agriculture will furnish material for your region. They may also have motion pictures that might be obtained. The Soil Conservation Service of the United States Department of Agriculture has much valuable general material. (See Bibliography.)

Procedure

This problem on soil conservation is the most important in the unit. To introduce the problem, pupils may take a field trip to add to the knowledge that they have already acquired about how the land is eroded. A motion picture or a scientist from the local Soil Conservation Service will help make this problem more meaningful. Have the pupils read and discuss pages 87-92. In the discussion, the importance of soil conservation to the children themselves as well as to the nation as a whole should be stressed. They should become acquainted with what is now being done in their locality to conserve the soil, with the plans for the future, and with the need for further planning.

Questions (Page 92)

1. We need the soil to grow the plants that keep us alive.
2. By wind and water.
3. By planting trees on steep slopes, grass on rolling slopes, crops on gentle slopes.
4. Wind and water carry away bare soil.
5. They eat the grass so close to the ground that the grass cannot keep water or wind from carrying the soil away. Soon the top layer of soil is gone, and plants will no longer grow.

Questions to answer (Pages 92-93)

1. Pupils should find out something about the history of the region in which they live and how it came to be the way it is, as well as look for smaller changes in the immediate vicinity.
2. List may include material from the unit, such as: rivers and streams cut valleys and make islands; rocks are worn down and broken up; water and wind carry away sand and soil and pile it up in other places; glaciers scoop out rocks and soil and deposit them in ridges; mountains are made by volcanic action and forces within the earth. Answers to the second part can be drawn from the unit and from observations.
3. Gravity pulls everything downward including water, air, rock, soil, ice, lava, ash, etc. It causes rocks to fall from mountains and makes water run downhill, carrying sand, soil, and rock with it. It causes sand to fall from the air, glaciers to move downhill and drop their loads of soil and rock, rain to fall, etc. Because it pulls harder on heavier things, warm air is forced up and the wind blows, molten rock is forced up, and volcanoes erupt.
4. It may be pressed into rock at the bottom of the ocean. That rock may someday be forced upward to the surface or may even form a mountain. Then pieces of the rock may be broken off by water, heating and cooling, etc. Water and other things break the rock into smaller and smaller pieces until it is sand that can be blown by the wind.
5. As it was carried by the stream, it rolled over and over and rubbed against other stones. Bits of the brick were broken off until it became smooth and round.

6. Mud and sand were washed from the land by rain and melting snow and carried off by rivers. The rivers finally emptied into the ocean, where particles in the water settled to the bottom.

7. Heating and cooling, freezing water, plant roots, moving water, wind, and glaciers may be mentioned.

8. When it carries away soil that is necessary for plant growth, it is very harmful. But when it grinds up rock to make soil and wears down mountains, it is helpful.

9. Answers individual but should be based on the text.

Things to do (Page 93)

1. Individual reports.

2. Land at the mouth of the river (the delta) is built farther and farther out into the gulf. This land is a very low plain through which the river flows very slowly, often changing its course and sometimes flooding.

3. Lava may vary in color and form, depending on the minerals of which it is composed. The structure of some pieces will show that it was once a liquid.

4. *Vesuvius*, in Italy on the Bay of Naples, has been intermittently active since the year 79. The last large eruptions were in 1906 and 1944. The present active cone has grown up around a vent on the southern side of a much greater prehistoric crater. It is the only active volcano on the European continent.

Etna, on the east coast of Sicily, is the highest volcano in Europe, rising over 10,000 feet. It has been intermittently active since prehistoric times. A destructive flow of lava occurred in 1928. In 1947, eruptions caused new craters to be formed. The land at its base is extremely fertile, yielding as many as five harvests a year.

Krakatoa, an island in the East Indies, was one of several cones within the great crater ring of a former volcano. There are a few reports of earlier disturbances, but none compare with that of 1883. Eruptions began in May. On August 27, four great explosions blew up most of the island, leaving a subterranean cavity 1000 feet below sea level. Dust and ash were carried thousands of miles. Rocks and pumice made new islands, while great waves swept away former ones. Disturbances in the air went around the earth four times.

Pelée, largest of several volcanoes on the island of Martinique in the French West Indies, has erupted three times in recorded history. The last and most devastating eruption was in 1902, when two explosions destroyed two towns and killed many thousands of people.

Chimborazo, Ecuador, is one of the highest mountains of the Andes. Although it has no crater, it is built on volcanic rock and so is really an extinct volcano.

Mauna Loa, in south central Hawaii, has a very large crater floored with hard lava, which steams in places. It erupts about every five years. On its eastern slope is the still larger crater of *Kilauea*, which contains a lake of liquid fire and smokes almost constantly. It is known that the two volcanoes are not connected, for both are active independently.

Fujiyama, the sacred mountain of Japan, is located some 60 miles southwest of Tokyo. It last erupted in 1707-1708. The highest mountain in Japan, it is known for its beauty because it is simple in form and stands isolated.

5-6. Individual or group activities.

7. Rocks will vary a great deal. Weathering often changes the outside of a rock so that it has a different color.

8. Individual or group activity. Railroads and resorts can often supply pictures.

9. All keep the soil from being washed down or blown away. (See the picture on page 90 for contour plowing and strip cropping.)

10. Fields would otherwise be bare and exposed to erosion by winter weather.

11. These minerals are found in coarse-grained igneous rocks like granite. The hot, liquid rock cooled very slowly far underground. The minerals separated and formed crystals. Quartz crystals look like glass. Feldspar is usually white or pink. Mica is often black.

UNIT 4. *How Do Germs Make You Sick?*

Purpose and scope

The concepts presented in this unit have practical value only if they function in daily life. Whether pupils apply what they learn depends largely on the attitude they acquire. Therefore, this unit strives to develop an intelligent and cooperative attitude toward personal and community health by explaining the "why" and the "how" of good health practices. As the reasons for health precautions come to be understood, this attitude should become evident in the pupils' behavior. For example, they should make sanitary use of the drinking fountain, show care with colds, and be willing to follow the directions of the school doctor or nurse.

The continuing conquest of germ diseases is an inspiring story of patience, courage, and self-sacrifice. Through a study of this unit, pupils should become aware of the enormous contribution of science to their well-being. They should also have increased appreciation for the methods and results of scientists' work.

Science background

Discovering Our World, Book One: Unit 3, How Does Your Body Work? Unit 7, How Can You Keep Well?

Discovering Our World, Book Two: Unit 1, How Do Living Things Help and Harm Each Other? Unit 5, What Are Things Made Of? Unit 7, Why Do You Need Food?

General concepts

1. Many diseases are caused by germs.
2. The invention of the microscope made it possible to find out about germs and to develop modern methods of fighting germ diseases.
3. There are several kinds of tiny plants and animals classed as germs.
4. Not all diseases are caused by germs.
5. When bacteria and other germs get into your body, they cause chemical changes that make you sick.
6. Bacteria and other germs multiply very fast.
7. Bacteria and other germs are in or on almost everything.
8. Germs can be spread easily from place to place and get into your body.
9. Your body has ways of preventing germs from getting in.
10. Your body has ways of destroying germs that do get in.
11. Vaccines, serums, and drugs are chemicals prepared by scientists to help your body destroy germs.
12. The spread of germs can be prevented by proper precautions.

Introducing the unit (Page 95)

The unit may be introduced by asking pupils to tell any experiences they may have had with diseases. A child who has recently been absent because of illness will probably have a good deal to contribute. He can tell the class what disease he had, how long he had it, how he felt, what he had to do, if he were quarantined, etc. Another child may wish to tell the class about a younger brother or sister who has had some contagious disease. Evidence of colds or a quarantine sign in the community can also be used to start the pupils thinking about the unit and raising questions.

Have the pupils read the introductory section on page 95 and discuss the pictures on pages 94 and 95. The activity suggested in the last paragraph should also be carried out. The list of questions may be written on the board and kept before the class as the study of the unit progresses.

How have scientists learned about germs? (Pages 95-99)

Concepts

1. Many diseases are caused by germs.
2. The invention of the microscope made it possible to find out about germs and to develop modern methods of fighting germ diseases.
3. There are several kinds of tiny plants and animals classed as germs.
    a) Bacteria cause many diseases, but most bacteria are harmless and others helpful.
    b) Some yeasts and molds cause diseases.
    c) Certain tiny animals cause diseases.
    d) Viruses are usually classed as germs.
4. Not all diseases are caused by germs.

Information for the teacher

Pictures. Page 96. Van Leeuwenhoek lived from 1632-1723. See Bibliography for references.

Page 97. *Left.* Pasteur lived from 1822-1895. *Right.* Robert Koch lived from 1843-1910. See Bibliography.

Page 98. *Left.* The typhoid germ is a large rod or bacillus having whip-like appendages called *flagella* by which the organisms can move with great speed through liquid mediums. These flagella are one of the characteristics used in classifying bacteria; a special stain is used to bring them out. *Right.* The sleeping-sickness germ is a *protozoon*, or one-celled animal. This kind of sleeping sickness is the African sleeping sickness. The germ is carried by the tsetse fly, which passes it on to people when it bites them. Certain kinds of the germ infect animals, too, so that parts of Africa can scarcely be inhabited because of this disease. The other kind of sleeping sickness called *encephalitis*, which occurs in the United States, is caused by a virus.

Page 99. *Left.* The whooping-cough germ is a very tiny rod-shaped bacterium. *Right.* The diphtheria germ is a slender, rod-shaped bacterium. Sometimes it appears to look like a tiny club.

Text. Some of the "little animals" that Leeuwenhoek saw were chiefly protozoa, but he also saw one of the largest bacteria, one of the long, spiral forms often found in the mouth. Just as with other plants, there are wild yeasts and cultivated yeasts. The kinds of yeasts that one finds in a yeast cake are cultivated; that is, they have been raised in pure cultures so that bakers and brewers can be sure of the kind of yeast they are getting. There are many wild yeasts floating around in the air. Probably some of the smooth colonies that grow in the Petri-dish experiment in the next problem will be yeasts. Yeasts are also the cause of certain diseases, such as some kinds of ulcers and skin diseases. There will be more about yeasts in Unit 9.

Viruses are so tiny that they cannot be seen with optical microscopes. However, scientists have recently been able to photograph some of them by using the electron microscope, which magnifies objects up to 200,000 times their actual size. In some ways, viruses seem to be alive; they grow and reproduce only on living things. In other ways, viruses appear to be non-living; they are giant protein molecules that crystallize. Some scientists believe that viruses may be a link between non-living and living matter and thus a clue to life itself.

Procedure

This problem may be introduced by raising some questions. Ask the pupils why they think that the discovery of germs was so important. After the discussion, ask them how they think that this discovery was made. Have them recall that germs are very tiny plants or animals. Then the pupils should read and discuss pages 95-99.

The story told in the text illustrates an important fact: Great discoveries are seldom, if ever, made by just one scientist. Without the microscope invented by Van Leeuwenhoek, Pasteur could not have seen the bacteria on the silkworms. Koch's work was made possible by Pasteur's discoveries. Pupils may wish to read about other scientists not mentioned in the text and then report to the class. For an additional activity, see *Things to Do,* page 119, No. 5.

Questions (Page 99)

1. Very tiny plants or animals that can cause diseases. Bacteria that cause tuberculosis, typhoid fever, and diphtheria. Yeasts and molds. Tiny animal germs that cause malaria and sleeping sickness. Viruses that cause colds, influenza, smallpox, mumps, and measles.

2. (*a*) No. Other plants besides bacteria are germs. Some germs are animals; others are viruses. (*b*) No. Most bacteria are harmless. Some are helpful, such as those that change cider to vinegar or milk to cheese. (*c*) No. Diseases may also be caused by improper food, lack of certain vitamins, allergies, worry, fear, etc.

3. He was studying wines to try to find out what made them spoil. Besides the yeasts that he knew caused the sugar to turn to alcohol, he found some other tiny living things, bacteria. He also found bacteria in some milk that had become sour. From these discoveries he began to wonder whether bacteria might cause diseases. When asked to find out what was killing the silkworms, he looked for and found bacteria on the silkworms. By feeding these bacteria to healthy silkworms, he was able to show that some bacteria cause disease.

4. By enabling scientists to find the cause of many diseases, many lives have been and will be saved.

How can you grow bacteria? (Pages 100-103)

Concepts

1. Bacteria can be killed by sufficient heat and in other ways.

2. Bacteria can be grown by supplying food, warmth, and darkness.

3. When bacteria and other germs get into your body, they cause chemical changes that make you sick.

4. Bacteria are ball-shaped, rod-shaped, or spiral-shaped.

5. Bacteria and other germs multiply very fast.

Experiment

PAGES 100-102: To grow some bacteria.

MATERIALS: Six Petri dishes, nutrient or potato agar, cotton, six test tubes, hot oven for baking dishes, container in which test tubes can be boiled, gummed paper for labeling and sealing dishes, pencil, milk, coin, warm, dark place where dishes can be kept.

Information for the teacher

PICTURES. PAGE 102. *Left. Escherichia acidilactici*, common milk-souring organism. *Right. Staphylococcus aureus*, organism found in boils, infected wounds, bone diseases, etc.

PAGE 103. *Left. Streptococcus mitior*, organism present in sore throats and other secondary infections. *Right.* Giant *spirillum*, a very large organism found in fresh water cultures, used mainly for study of flagella.

TEXT. PAGES 100-102. The standard medium for growing bacteria is agar to which suitable nutrients have been added. The agar itself is not a nutrient; it is the solidifying agent. You may obtain from supply houses test tubes filled with the correct amount of medium ready for pouring, or a flask containing the medium ready to be melted and poured. Or you may obtain a dehydrated medium called nutrient agar, which needs only to be combined with water according to the directions on the bottle. (Nutrient agar has beef broth as its chief nutrient.) However, a very satisfactory agar medium can easily be made; and making the medium adds much to the experience of growing bacteria. The medium given below is potato agar. Agar can be purchased at a drug store, usually in the form of long shreds.

Peel three potatoes and wash them. Cut them into thin slices and boil them in a quart of water for eight or ten minutes. Leave the potatoes in the water and pour off a pint of liquid. Strain this liquid through a clean white cloth.

Cut half an ounce of agar into small pieces and drop them into the liquid. Stir the liquid and the agar and let it stand for ten minutes. Now heat the agar until you are sure it has completely dissolved. Complete solution of agar requires a boiling temperature and may take a little time. When the agar is completely dissolved, strain the liquid again. To make straining easier, heat the cloth by pouring boiling water through it. Bring the volume of liquid up to a pint if some has been lost during the boiling. Then pour the liquid into the test tubes. Fill each test tube about half full. Plug the test tubes lightly with a wad of cotton batting.

Stand the test tubes in a small pan containing about three inches of water. If possible, put a small piece of wire screening on the bottom of the pan so that the test tubes do not rest directly on the bottom of the pan. Boil them slowly for forty-five minutes. Allow the test tubes to cool overnight. The next day boil them again for the same length of time. The agar is then considered sterilized and ready to be placed in the Petri dishes when needed.

The Petri dishes must be sterilized, too. This may be done in a hot oven. Wrap the dishes in newspaper (the six in one package) and heat to about 350° F. for one hour. Keep the dishes wrapped in the paper until they are used.

When you want to pour the food into the Petri dishes for use, heat the solid agar in the test tubes until it is completely liquefied. When pouring the agar into a dish, lift the cover just enough to insert the mouth of the test tube, as shown in the picture on page 100.

Page 103. Under ideal conditions, one bacterium will divide and multiply into 16,777,216 bacteria in twelve hours.

Procedure

The food for the bacteria experiment must be prepared in advance. Unless the food and Petri dishes are sterile, the results of the experiment will be unreliable. Follow the directions given above. If some of the pupils wish to help in the preparation, supervise their work carefully. The pupils can report what they did before the class begins the experiment.

If at all possible, the experiment should be done because it provides dramatic evidence of the widespread occurrence of bacteria. Children who bite their fingernails or put pencils, coins, and fingers in their mouths will be less likely to continue these unsanitary habits when they observe the results. The directions for planting the dishes must be carefully followed. Although the bacteria grown in the dishes may be harmless, do not let the pupils touch the growths. The dishes, each accompanied by an explanation, may be kept for a time and used as an exhibit.

After the experiment has been performed and the results observed, have the pupils read the rest of the problem and examine the pictures on pages 102-103. They should also complete the table begun on page 103. The total number of bacteria will astound them.

Questions (Page 103)

1. To kill any bacteria already on them.
2. The cotton prevented more bacteria from getting in while the heat sterilized the food.
3. To prove that the live bacteria did not come from the food.
4. All are plants that have one cell. They have different shapes.
5. By dividing into two smaller plants that grow to full size and divide.
6. Because some bacteria cause chemical changes inside your body and can make you sick.

How do germs get into your body? (Pages 104-107)

Concepts

1. Bacteria and other germs are in or on almost everything.
2. Germs can be spread easily from place to place and get into your body.
    a) Air or moisture from a sick person's nose or mouth, or his dishes, clothing, etc., may spread germs.
    b) Impure water, milk, and other foods may spread germs.
    c) Flies carry germs on their bodies and spread disease.

d) Insects such as mosquitoes, lice, fleas, etc., may spread germs by biting people.

e) Rats and mice carry lice and fleas on their bodies and spread disease.

Information for the teacher

Pictures. Page 106. The lamps are slender, gas-filled tubes that give off ultraviolet rays which kill bacteria. The rays are given off when an electric current passes through the gas in the tube.

Page 107. Be sure that the children understand that the trail of bacteria from the fly's feet was made when the bacteria grew into visible colonies on the plate. The bacteria on the fly's feet are too small to see. But when they are deposited in a place favorable for growth, they multiply and form colonies that are visible. This will be clear if the pupils recall the experiment in the preceding problem.

Procedure

Pupils will usually bring to this problem a good deal of information from personal experiences and earlier science study. The problem is intended as a review, clarification, and summary of this information. Have the pupils use the concepts developed in the preceding problems to recall what they already know about how germs get into their bodies. Write on the board the various ways that are mentioned by the pupils in which germs are spread. Then let them read the text and examine the pictures. The list on the board should now be revised and any additions made. Keep the final list, since it will be used again in the last problem of the unit. For additional activities, see *Things to Do*, page 119, Nos. 4 and 7.

Questions (Page 107)

1. Through cuts, burns, or other skin openings; by breathing air or eating food that has been exposed to the spray from coughing and sneezing; by putting germ-covered pencils, fingers, etc., in the mouth; by handling things used by a sick person; from impure water, milk, or other foods; from flies that leave germs on food; from mosquitoes, lice, and fleas that bite sick people.

2. The other person may be sick, and so the cup or glass may have germs on it.

3. To keep the germs in the spray from spreading.

4. *Page 104:* The paper towel; bandaged knee; using a handkerchief. *Page 105:* Washing fruit; drinking from a fountain. In each of these pictures, care is taken not to let germs into the body.

5. Anything that you touch may have had germs on it. If your unclean hands then touch food, the germs may easily get into your body.

How does your body fight germs? (Pages 108-110)

Concepts

1. Your body has ways of preventing germs from getting in.

   a) Your skin keeps many germs from ever getting inside your body.

   b) Tiny hairs and a sticky liquid in your nose stop some of the germs that are breathed in.

2. Your body has ways of destroying germs that do get in.

   a) White corpuscles in your blood gather at the place where the germs are and kill them.

   b) Your body makes materials that kill germs, weaken them, or destroy the poisons.

   c) Your body can make these germ fighters more easily if it is well and strong.

Information for the teacher

Picture. Page 109. There are several kinds of white corpuscles. Two kinds are shown in this picture. White corpuscles are classified according to size, shape of the nucleus, and the way in which they stain. Some are known as *phagocytes* (cell eaters) because they eat or dissolve cells, such as bacterial cells.

Text. The sticky liquid in the nose is called *mucus*.

Procedure

At this point in the unit, some of the pupils may begin to wonder why they are not sick most of the time, as indicated in the first paragraph on page 108. To introduce the problem, ask the pupils why they think it is important not to cut or burn themselves. Also ask why cuts or burns should be promptly taken care of and refer to the picture on page 108. The questions will bring out the concept that the skin keeps many germs from getting into the body. Now have the pupils read and discuss the first three paragraphs on page 108.

Then ask what happens when germs do get into the body. Have the pupils recall what they learned on pages 102-103. (When germs get into your body, they cause chemical changes that make you sick. Germs multiply very fast.) Let the pupils read the next three paragraphs, which summarize and extend these concepts.

Pupils are now ready to read and discuss the rest of the problem. Stress the fact that your body can fight germs better if it is well and strong. Have pupils recall some of the ways in which they can keep their bodies healthy, such as eating the proper foods, getting the right amount of exercise and rest, keeping your skin clean, etc.

Questions (Page 110)

1. Skin; tiny hairs and the sticky liquid in the nose.

2. They settle in the place where they can live best and begin to grow and multiply by using your body for food. As they grow, they make toxins, which get into your blood.

3. White corpuscles in the blood pass into cells where germs are and eat the germs. Also, certain cells make materials that can kill germs, make germs more appetizing to white corpuscles, or change toxins to make them harmless.

4. A toxin is a poison. An antitoxin is a material that changes toxins and makes them harmless. Your body makes antitoxins. Germs make toxins.

How do scientists help your body fight germs? (Pages 110-112)

Concepts

Vaccines, serums, and drugs are chemicals prepared by scientists to help your body destroy germs.

a) Vaccines prevent disease by causing your body to make antitoxins that make the germs harmless.

b) Serums prevent disease because they contain antitoxins.

c) Scientists have discovered several new drugs that will kill bacteria which get into the body.

Information for the teacher

PICTURES. PAGE 110. A doctor examines a boy's throat by use of a tongue depressor and light reflected by a head mirror.

PAGE 111. Boy is being vaccinated.

PAGE 112. This serum is used as a preventive against tetanus, gas gangrene, scarlet fever, diphtheria, and other diseases.

TEXT. This problem deals with *immunity* given to the body by vaccines and serums, and with certain drugs that have been developed to fight bacterial infections. The type of immunity produced by vaccines is called *active immunity*, because the body itself is active in producing the antibodies (antitoxins), etc. The body is stimulated to produce the antibodies by the introduction of the bacteria themselves or the toxin produced by the bacteria as they grow. The type of immunity conferred by a serum is called *passive immunity*, because the body that receives it has not made the antibodies. They have been made in the body of some animal (such as a horse in the case of diphtheria antitoxin) or in the body of someone who has had the disease.

The first sulfa drug was sulfanilamide. This had certain bad effects, so that many other sulfa drugs were prepared and tried out. Today, the most common sulfas are sulfadiazine and sulfathiazole. Penicillin is made by a mold, *Penicillium notatum*, which is related to one kind of bread mold. An even newer drug, streptomycin, is also made from a one-celled plant, *Streptomyces griseus*. This drug has shown encouraging results in the treatment of tuberculosis.

Procedure

A good way to introduce this problem is to ask the pupils who have been vaccinated to raise their hands. Practically all of them should do this. Let them tell how and when they received the vaccination. They should also mention the disease for which they were vaccinated. Ask them whether they had the disease afterwards. Then say, "Do you think vaccination is a good way to prevent this disease? Why do you think so?" After the discussion, have the pupils read the first three paragraphs to check their conclusion and to find additional information.

Many of the pupils will have had "shots," or inoculations, for diphtheria, whooping cough, and possibly scarlet fever. However, since these are usually given early in life, the children may not recall them. If necessary, have the pupils ask their parents or the family doctor whether they received "shots" for any of these diseases. The inoculations are made with various serums, which may be given either before or after the disease is contracted. Some of the pupils may have had measles serum. As with vaccines, raise questions and then have the pupils read the next two paragraphs of the text to find out about serums.

The rest of the problem deals with the so-called "miracle" drugs, the sulfas and penicillin. Some of the pupils or members of their families have undoubtedly taken these drugs during an illness. Have the pupils read to the end of the problem and then discuss what they have learned. For additional activities, see *Things to Do*, page 119, Nos. 2, 6, and 8.

Questions (Page 112)

1. A liquid put into a person's body to prevent a disease. It helps the body produce antitoxins.

2. A liquid put into a person's body to prevent or cure a disease. It contains antitoxins that make toxins harmless.

3. New drugs such as the sulfas and penicillin have been discovered that will cure diseases from which people might otherwise have died.

How can we keep germs from spreading? (Pages 113-117)

Concepts

The spread of germs can be prevented by proper precautions.

a) Water, milk, and other foods should be kept pure and clean.

b) Garbage and rubbish should be cleaned up to help get rid of flies and rats.

c) Flies, mosquitoes, lice, and fleas should be destroyed.

d) People with diseases that can easily be carried to others should be quarantined.

e) Chemicals should be used to kill germs in sickrooms.

Experiment

PAGE 113: To find out how water is filtered.

MATERIALS: Lamp chimney, piece of cloth, piece of string or rubber band, clean gravel, clean sand, muddy water, two glasses.

Information for the teacher

In some places *certified milk* is often used. This is raw (unpasteurized) milk that is produced and bottled under such clean conditions that the milk can be certified to have an exceedingly low bacterial count. It is presumably safe as far as germs are concerned, and it keeps longer because of fewer milk-souring bacteria. However, there is always danger of infecting the milk at some stage in the production. For this reason and because the milk costs more due to the increased cost of meeting the production requirements, it is not so widely used as pasteurized milk.

Pasteurizing milk does not kill all the bacteria in the milk, but fortunately all the disease-producing forms are killed by this degree of heat. Milk-souring organisms and many other harmless bacteria are resistant to the temperature used in pasteurizing. Though these bacteria are harmless, the numbers present in the milk are an indication of the cleanliness surrounding the milk during production and handling. There are several grades of pasteurized milk. Grade "A" has the lowest number of bacteria both before and after pasteurizing.

Articles on the use of DDT appear in many of the current and recent magazines. DDT should not be used indiscriminately. It is poisonous to people, pets, and farm animals as well as many insects.

The terms *germicide* and *disinfectant* are often confused or used interchangeably with *antiseptic.* As the text indicates, *germicide* means germ killer; that is, the germ is actually killed. A disinfectant is also a germicide. An antiseptic, however, only inhibits the growth and activities of the germs. If the antiseptic situation is removed, the germs may start growing again. Some materials that are used as germicides may be only antiseptic in action if the solution is made weaker.

Procedure

To introduce this problem, refer to the list of ways in which germs get into the body. (See pages 104-107 of the text.) Ask the pupils how they can use what they have already learned to keep germs from spreading. Write the suggestions on the board. Then let the pupils read and discuss the first three paragraphs on page 113. Now have the pupils read the next paragraph and do the experiment. After they have observed the results, they should read down to the last paragraph on page 114. Then ask them to tell how the water they drink is made pure.

Before the children read the next two paragraphs about pure milk, have them examine the labels on milk bottles or cartons. The label should give the name of the dairy, the grade of milk, and the date (or day) before which it must be sold; it should also tell whether the milk is pasteurized or certified. The pictures at the top of page 115 can be used to start the study of the next paragraph, which deals with pure food. In a similar way, use the picture on page 116 to begin the study of insect control, which is taken up in the next three paragraphs.

The rest of the unit should now be read and discussed. If necessary, pronounce *quarantine*, *germicide*, *fumigate*, and *epidemic* for the pupils, or have them refer to Science Words for the pronunciation. To summarize the problem and conclude the unit, ask the school doctor or nurse to give a talk to the class. Pupils should be encouraged to look for places where germs may be spread at school, at home, and in the community. Individuals or groups may make these investigations and report their findings to the class. For additional activities, see *Things to Do*, page 119, Nos. 1, 3, 9, and 10.

Questions (Page 117)

1. A visit to or a talk by some member of a health board, sanitary board, a county nurse or doctor will help answer this.
2. Answers may include: by inspection of barns, cows, dairies, milk containers, and by pasteurizing the milk itself.
3. Many schools require regular physical examinations, maintain a doctor or nurse to treat or send home students who are ill, keep first-aid material on hand, keep careful checks on lunchrooms or any other handling of food, sterilize locker rooms, etc.
4. Keep away from others to prevent the spread of disease. Pupils may also tell about their own experiences.
5. List may include: water must be kept pure by filtering, spraying through air, adding chemicals, and testing; milk must be pasteurized; all dairies, milk containers, and handlers kept clean; stores and restaurants must be kept clean and all food protected or refrigerated; dirt and rubbish must be cleared away and burned and garbage collected frequently; mosquitoes and flies should be killed and buildings screened from them; sick people must be quarantined.

6. Answers may include: filtering, spraying, chemicals, and testing.

7. By spreading oil where they breed or spraying them with DDT.

Questions to answer (Page 118)

Pictures. *Left.* The water is tested frequently and known to be free of disease germs. *Right.* People who handle food must be very careful to wash their hands to remove any germs that might be on them. Germs are easily spread on food because it is a good place for them to grow.

1. Germs are too small to be seen by the naked eye. After the microscope was invented, scientists saw bacteria and then learned that some of them were germs.

2. Some diseases are more easily carried from one person to another.

3. The experiment was not done carefully. The dish or the food was not sterilized well enough, because no live bacteria should be in Dish 6.

4. Vaccine kept people from getting typhus. DDT killed the lice and fleas that carried the disease.

5. Boil it. By pasteurizing it.

6. List may include: clean and bandage cuts, burns, etc., immediately; keep fingers, pencils, coins, etc., out of your mouth; wash hands and, if necessary, food before eating; avoid sick people and any objects they have handled; insist on pure water, milk, and food; take frequent baths; blow your nose gently.

7. Stay home; call a doctor.

8. It can usually make enough white corpuscles or antitoxins to kill germs before they can make you sick.

9. Keep clean; eat the proper foods; get enough exercise and rest.

10. Wash hands frequently; use handkerchief when coughing or sneezing; stay away from people when sick; sterilize and fumigate after an illness, etc.

11. *Alike:* They are both put into your body to keep you from getting diseases. *Different:* Vaccine makes your body produce antitoxins. Serum contains antitoxins.

12. Horses help produce serum for diphtheria. When diphtheria toxin is put into a horse, its body produces antitoxins and pours them into the blood. Serum can then be made from this blood.

13. Many germs are carried by people; and so the more people in a place, the more germs there are to be spread. Also, closer contact spreads germs more easily.

Things to do (Page 119)

1. Individual or group activity. Many cities make complete reports every hour with extra checks every half hour or fifteen minutes, depending on weather or other conditions.

2 and 4. Encyclopedias and many medical books give these stories. (Also see pamphlets on health in the Bibliography.)

3. Individual or group activity.

5. Cows may have tuberculosis; sheep have anthrax, caused by bacteria. Cattle have hoof-and-mouth disease caused by a virus. Some common plant diseases are wheat rust, corn smut, apple scab, chestnut blight, wilts of tomatoes, asters, etc., all caused by fungi. Many other plant and animal diseases can be found by consulting encyclopedias, general botany, zoology, or biology texts.

6. Fleming discovered penicillin in 1929. But it was not purified until ten years later when Dr. Howard B. Florey directed work on it at Oxford, England. Its great value was not known until then. Only more recent books will contain information on its discovery.

7.

Disease	*Carried by*
Malaria	Mosquito (Anopheles)
Yellow fever	Mosquito (Aedes aegypti)
Typhus	Body louse, flea
African sleeping sickness	Tsetse fly
Rocky Mountain spotted fever	Tick on cattle and some wild animals
Plague	Fleas on rats

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8. Many current and recent magazines as well as encyclopedias have articles on the sulfa drugs. Sulfanilamide, used in infections with streptococci, gonococci, and meningococci, is the base from which most other sulfa drugs were made. Most common are: sulfapyridine for certain types of pneumonia; sulfathiazole for pneumococcus and staphylococcus infections; sulfadiazine for pneumonia, streptococcus and staphylococcus infections, and meningitis; and sulfaguanidine for bacillary dysentery and colonic surgery.

9. History books and encyclopedias give accounts of the Black Death of 1330 to 1350 and again (this time known as Bubonic Plague) in the seventeenth century. Some of the earliest recorded epidemics date back to Roman times. From then on, Europe was devastated at intervals by smallpox, leprosy, scurvy, influenza, measles, chicken pox, typhus, whooping cough, malaria, and other diseases that are difficult to diagnose due to conflicting reports. Periods of war nearly always brought epidemics.

10. Individual or group activity.

UNIT 5. *How Do We Use Electric Current?*

Purpose and scope

Everywhere in their daily living, pupils encounter electric current, as it is used to help them in many ways. This unit will help the children become better acquainted with this useful source of energy and learn to use it safely as well as to appreciate its importance. Since the usefulness of electric current and some of the fundamental facts about it are the essential ideas to be understood, technical terms have been kept to a minimum. The concepts developed in this unit furnish a valuable background for later study of science. For example, the next unit of this book deals with light, for which electric current is widely used.

Science background

Look and Learn: Unit 2, Machines

All Around Us: Unit 2, Getting Work Done

How Do We Know?: Unit 4, Wheels and Levers

Discovering Our World, Book One: Unit 6, What Can Magnets Do?

Discovering Our World, Book Two: Unit 2, What Makes Things Move? Unit 3, How Is Our Work Made Easier? Unit 5, What Are Things Made Of?

Discovering Our World, Book Three: Unit 1, What Makes Sound?

General concepts

1. Electric current can be produced by chemical change or by generators that use the energy of water, steam, wind, or exploding gas.
2. Electric current will flow only when there is a closed circuit.
3. Electric current always follows the shortest possible path.
4. Electric current flows through *conductors* but not through *non-conductors*, or *insulators.*
5. Electrical appliances and wires may be extremely dangerous if they are not used carefully or insulated properly.
6. Buildings are protected from short circuits by fuses and circuit breakers.
7. Electric current can be controlled by switches and transformers.
8. Electric current can be used to make heat.
9. Electric current can be used to give light.
10. Electric current can be used to make a magnet.
11. An electromagnet can make things move.
12. A telegraph, an electric bell, and an electric motor all work by using electromagnets.

Introducing the unit (Page 121)

Information for the teacher

Picture. Page 120. Part of Lake Shore Drive, Chicago, at night. The tall building with the beacon is the Palmolive Building. The beacon on top of this building was formerly called the Lindbergh Beacon but is now known as the Palmolive Beacon. It is used as a guide both by airplanes and boats approaching the city.

Procedure

To start this unit, let the children study the picture on page 121 and tell what they think it shows. Then have them read and discuss the story in the text. They may wish to tell about similar happenings in their own community. (In parts of the country where snow is uncommon, interruptions of electrical service are sometimes caused by strong winds, thunderstorms, floods, etc.)

Now raise some questions about what happened in the story and let the pupils try to answer them. For example, ask why the lights in the city went out when the wires snapped, how batteries could supply current, and how current was produced in the powerhouse. The pupils' answers should be revised as the study of the unit progresses.

Where does electric current come from? (Pages 122-126)

Concepts

1. Electric current can be produced by chemical change in a dry cell or a wet cell.
2. Electric current can be produced by generators that use the energy of moving water, steam, wind, or exploding gas.

Experiments

Page 122: To find out what is inside a dry cell.

Materials: Old, worn-out dry cell (No. 6 dry cell if possible).

Pages 123-124: To make a wet cell and show how it works.

Materials: Glass tumbler or small glass jar, sulphuric acid and water, strip of zinc and strip of copper, each one inch wide and five inches long, two to three feet of covered copper wire, small electric-light bulb and socket, small electric bell.

Information for the teacher

The active chemical in most dry cells is ammonium chloride, or sal ammoniac. There is usually some manganese dioxide in the mixture to prevent hydrogen from collecting on the carbon rod. Hydrogen on the carbon rod stops the chemical action of the cell. When the zinc is changed into a "soft, white powder," it becomes zinc oxide.

When mixing the water and sulphuric acid for the wet cell, *be sure to pour the acid slowly into the water*. If the water is poured into the acid, a dangerous spattering occurs. It is a good precaution to have some household ammonia or baking soda handy to neutralize any acid that may be spilled.

The drinking glass or glass jar used for the wet cell should be thin glass rather than thick, since thick glass may be cracked by the heat produced in mixing acid and water.

When making electrical connections, always be sure that the points of contact are clean and the connections tightly made; otherwise the current cannot flow.

The bubbles that collect on the metal strips in the wet cell are bubbles of hydrogen. Consult a high-school general science or chemistry text if further details about the chemistry of dry and wet cells are desired.

Procedure

Ask the pupils to name the two sources of electric current mentioned in the story on page 121 (powerhouse, batteries). Have them recall the concepts relating to electrical energy and the transformation of energy in *Discovering Our World, Book Two*, Unit 2, and those relating to chemical change in Unit 5 of the same book. The important concepts to be recalled are as follows:

1. Electric current can be made in two ways.

   a) Electric current is made to flow by a machine that is run by some other force.

   b) Electric current is made to flow by an electric cell.

2. One form of energy can be changed into another form of energy.

Now have the pupils examine a dry cell, following the directions and using the picture on page 122. Then let them read to the end of the first paragraph on page 123 and discuss what they have learned. Stress the fact that a battery really means two or more cells connected together.

The pupils should next perform the experiment with the wet cell described and illustrated on page 123. Warn them not to touch the acid or get it on their clothing. If the cell is properly made and connected, it will produce enough current to light a small bulb or ring a small bell. Now let the pupils read and discuss the text down to the end of the first column on page 124. If a storage battery is available, they should examine it. They may also wish to carry out the activity suggested in *Things to Do*, page 155, No. 3.

The rest of the problem deals with the source from which we get most of our electric current. Before or after reading and discussing the text, the children should have an opportunity to see a generator in operation. If possible, they should take a trip to the local powerhouse (or substation), as suggested in *Things to Do*, page 155, No. 1. (In communities where there are no power lines, pupils may observe generators in farm power plants or in automobiles.) Another activity is given in *Things to Do*, No. 9.

Questions (Page 126)

1. A chemical change must take place.
2. The chemical change stops. Then no more current can be made.
3. A battery is two or more cells connected together.
4. Unlike a storage battery made of wet cells, a dry cell, when dead, cannot be charged to supply current again.
5. *Moving water.* Water from a dam or waterfall rushes through the turbine, making the generator turn. *Steam.* Burning coal or some other fuel changes water to steam, which is forced against the blades of the turbine, making the generator turn. *Moving air.* Wind turns a windmill that is connected to a generator. *Exploding gas.* When gas explodes in a gasoline or Diesel engine, it pushes with enough force to turn a generator.
6. Answers will vary with the community. Probably steam or moving water.

How do we connect electrical appliances? (Pages 127-129)

Concepts

1. Electric current will flow only when there is a closed circuit, or path from the source of the electric current through the appliance and back again to the source.
2. Electrical appliances may be dangerous if they are not handled properly and used carefully.

Experiments and observations

PAGE 127: To show that electric current flows only in a closed circuit.

MATERIALS: Two pieces of insulated copper wire, small electric-light bulb and socket, dry cell.

PAGE 128: To observe the circuit in an electric cord.

MATERIALS: Cords of electric iron and toaster.

Information for the teacher

PICTURE. PAGE 129. The meter may be on the outside or inside of the house. If three wires enter the meter, two of them are “hot wires” and the other is the ground, or neutral, wire.

TEXT. This problem develops the concept of a circuit, which is essential to an understanding of how we use and control electric current. Every complete circuit consists of at least three parts: (1) a source of current (cell, generator), (2) a path for the current (usually wires), and (3) a device to use the current (light bulb, toaster, bell, motor, etc.). The preceding problem dealt with the principal sources of current. This problem is concerned primarily with the path for the current. Later problems will take up some of the devices that use the current.

Procedure

To introduce the problem, let the pupils try to answer the question stated in the problem title. They will probably say that they connect an electrical appliance by plugging it in or turning a switch. Then raise questions such as, "Why must you do this?" "What happens when you do it?" etc. Write the answers on the board and then have the pupils do the experiment described and illustrated on page 127. Every child should have this experience, since a knowledge of the meaning of open and closed circuits is necessary to an understanding of the rest of the unit.

After the pupils have read and discussed the text down to the second paragraph on page 128, let them examine the cords of electric irons and toasters and then read to the end of page 128. The children may wish to trace the wires that bring electric current to their homes or to the school building. If a new building is being constructed in the community, try to arrange a trip to see how the wires are being installed.

The children should now read and discuss the last paragraph and the safety rules on page 129. Needless to say, these rules and similar ones in the next four problems should be thoroughly understood and faithfully followed. Thousands of tragic accidents occur every year because people are careless in using electric current. To bring this fact forcefully to the pupils, urge them to carry out the activity suggested in *Things to Do*, page 155, No. 12.

Questions (Page 129)

1. A circuit through which current will flow. A circuit that is broken so that current will not flow.

2. It becomes an open circuit, and the current stops flowing.

3. It goes from the outlet through one prong at the end of the cord to one wire in the cord, through the socket into one prong of the appliance, through the appliance, back out the other prong, through the socket and the other wire in the cord, and out the other prong of the cord to the outlet.

4. Yes. If not, there would be no current.

5. If you do not, you can be badly burned or even killed.

Why are electric wires covered? (Pages 130-132)

Concepts

1. Electric current always follows the shortest possible path.
   - *a*) When electric current leaves its intended path and follows a shorter one, a short circuit is produced.
   - *b*) A short circuit prevents the electric current from reaching the appliance intended for its use.
   - *c*) A short circuit makes wires get hot enough to start a fire.
   - *d*) To prevent short circuits, insulated wires are used.
2. Electric current flows easily through materials called *conductors* but not through materials called *non-conductors*, or *insulators*.
3. Electric wires may be extremely dangerous if they are not properly insulated.

Experiments

PAGE 130: To find out what a short circuit is.

MATERIALS: Dry cell, small electric-light bulb and socket, bare copper wire.

PAGE 131: To show why wires are insulated.

MATERIALS: Dry cell, small electric-light bulb and socket, insulated copper wire.

PAGES 131-132: To show that wires are heated when a short circuit takes place.

MATERIALS: Same as for page 130.

Information for the teacher

PICTURE. PAGE 131. Different kinds of glass and porcelain insulators.

Procedure

Follow the same general procedure used in the preceding problem. Raise questions and let the pupils try to answer them. For example, if the pupils traced the wires in their homes or school, or visited a building under construction, ask them whether the wires were bare or covered. Ask the same question about the wires used in the experiment on page 127 and the cords for electrical appliances. Now ask why they think electric wires are covered. Then have the pupils do the experiments and check their findings by reading the text. The safety rules on page 132 should then be read and discussed.

As an additional activity, the pupils may wish to plan and carry out an experiment to find out whether various materials are conductors or non-conductors. Use the same apparatus as that pictured on page 130 but cut one of the wires. Then connect the ends of this wire to different materials. Use articles made of wood, glass, porcelain, rubber, cloth, plastics, and metals. The carbon rod from an old dry cell may also be tested. If the bulb lights, the material is a conductor. Only the metals and the carbon will conduct electric current. (If water is tested, it will not conduct current. One dry cell does not have enough voltage, or electrical pressure, to force current through water. At the much higher voltage used in buildings, ordinary water is a conductor of electricity.)

Questions (Page 132)

1. See the picture, page 130.
2. Non-conductors are used to cover and insulate wires. Current will not flow through a non-conductor. The covering must be scraped off to be sure that current will flow through the circuit at the places where connections are made.
3. (*b*), (*d*).

How do we protect our buildings from short circuits? (Pages 133-135)

Concepts

1. Buildings are protected from short circuits by fuses and circuit breakers.
2. To use fuses safely, certain rules must be followed.

Experiment

PAGE 133: To show how a fuse works.

MATERIALS: Plug-type fuse, block of wood, strip of tin foil, two pieces of insulated copper wire, thumbtacks, dry cell.

Information for the teacher

PICTURES. PAGE 134. This is the common plug-type fuse. The size used in most circuits is labeled "15 A" or "15 Amps," which means 15 amperes, the largest current that the fuse will carry without melting. Fuses for currents larger than 30 amperes are usually of the cylindrical, or cartridge, type.

PAGE 135. The circuit breaker shown here, in very simplified form, is the *thermostatic* type, which is operated by heat. The strip is made of two different metals firmly fastened together. As the metals are heated, one expands faster than the other, bending the strip and opening the circuit. Another type of circuit breaker, the *electromagnetic*, is operated by an electromagnet. This type is sometimes used on machines, such as washing machines, which are run by electric motors.

TEXT. When the conductors in a circuit carry more current than they were designed to carry, an *overload* occurs. This may be caused by attaching too many appliances at one time or by a short circuit, which is really a severe overload.

Procedure

Have the pupils read and discuss the first two paragraphs on page 133. Many of the children will have had experiences like the one described in the second paragraph. Let them tell about these experiences, describing what happened and what was done to turn the current on again. Now ask, "How do you think a fuse can turn the current off?" To find the answer to this question, the pupils should examine a new fuse and do the experiment described and illustrated on page 133. Then have them check their conclusions by reading down to the last paragraph on page 134 and studying the pictures.

After the pupils have read and discussed the last paragraph and the picture on page 135, they should study the safety rules. Rule 3 should be given careful attention, as some pupil is almost sure to report using a coin to replace a burned-out fuse. An experiment will show why this is a dangerous practice. Repeat the fuse experiment, using a penny or a piece of copper wire in place of the tin foil. (Pennies are made of copper.) The coin or copper wire will get hot, but it will not melt and open the circuit. Point out the fact that the wires leading to the block also get hot. Compare them with the wires in a building. Even if the overheated wires do not start a fire, they may melt. Then an expensive job of rewiring will have to be done.

An additional activity is suggested in *Things to Do*, page 155, No. 5. The school janitor or engineer will probably be glad to show the pupils where the fuses are that control the current to their schoolroom. Pupils should also be encouraged to look for fuses or circuit breakers in their homes.

Questions (Page 135)

1. It makes wires so hot that they sometimes start a fire.
2. (*b*), (*d*), (*a*), (*e*), (*c*).
3. Circuit breakers can be reset; they do not have to be replaced as fuses do.

How do we control electric current? (Pages 136-137)

Concepts

1. Electric current can be turned on or off by closing or opening the circuit with switches.
2. Electric current can be made stronger or weaker by using a transformer or more cells.

Experiment

Page 136: To show how a push button works.

Materials: Electric push button, electric bell, insulated copper wire, dry cell.

Information for the teacher

As mentioned earlier in this unit, every circuit consists of at least three parts: a source of current, a path for it, and a device to use it. Most of the circuits that we commonly use contain a fourth part: some type of switch to turn the current on or off. This problem discusses this additional part of a circuit and also mentions transformers.

In the push-button experiment, one dry cell may not provide a strong enough current to ring the bell. Larger bells will not operate unless two or more dry cells are connected together as shown in the picture on page 145. If you wish, you may use a small electric-light bulb and socket, as in the earlier experiments, instead of an electric bell.

Besides the push button, another common kind of switch is the knife switch, shown in the picture at the left on page 154. The metal lever comes into contact with the metal grip below it, thus closing the circuit. The knife switch stays closed without holding it down. To open the circuit, the lever must be pulled up again. Other kinds of switches are snap switches, toggle switches, and telegraph keys.

A familiar kind of transformer is the one seen on many light poles. It is usually a square or cylindrical box hung near the top of the pole. A transformer changes the voltage of electric current. A *step-up* transformer increases the voltage, and a *step-down* transformer decreases it. A transformer on a pole near a house decreases the high voltage (6900 or 2300 volts) of the power line to a voltage (115-230 volts) that can be used in the house. The small transformer used for electric trains further decreases the voltage of the house current to the 5, 10, or 15 volts that the motor of the toy train can use.

Procedure

Have the pupils recall what they did in the experiment on page 127 and in the experiments that followed. Raise questions such as, "How did you make the bulb light?" "How did you make the tin foil melt?" etc. The answers should bring out the fact that in each case something was connected to a dry cell, the source of electric current. Connecting the bulb or tin foil in this way made a closed circuit. Now ask, "How did you turn the bulb off?" "What happened when the tin foil melted?" The answers should indicate that in each case the connection was broken and the circuit was opened. Then say, "Do you think there is an easier way to turn electric current on or off?" "How do we turn the lights on and off in this room?"

The pupils should verify their answers by doing the experiment on page 136 and reading the text down to the last paragraph on that page. Be sure that they use the pictures. Then they should examine as many types of switches as possible to see how the switches control electric current. Now the pupils are ready to study and discuss the rest of the problem, including the safety rules. For additional activities, see *Things to Do*, page 155, Nos. 2 and 10.

Questions (Page 137)

1. It turns the current on or off by closing the circuit or by opening it.
2. Connect several dry cells together.
3. Close and open the circuit by connecting and disconnecting wires.
4. A transformer decreases the current so that the right amount of current flows through the motor or bell. The house current is too strong.

How do we use electric current to make heat? (Pages 138-139)

Concepts

1. When electric current flows through a wire that is a poor conductor, the wire becomes hot.
2. In electrical heating appliances, the heating element is a poor conductor.

Experiments and observations

PAGE 138: To find out how electric current is changed to heat.

MATERIALS: Dry cell, short piece of iron wire.

PAGE 138: To observe the heating element of an electric iron.

MATERIAL: Old electric iron that can be taken apart.

Information for the teacher

The wire used in many heating elements is nichrome, a wire that has been especially developed for this purpose. It is a mixture, or alloy, of nickel and chromium that does not melt or burn when red-hot. The wire is wound around some insulator, such as mica or porcelain. Mica is a transparent mineral that splits into thin and somewhat flexible sheets. Sometimes it is called isinglass. When the wire has been properly mounted on the insulator, it is put into the iron, toaster, or other heating device.

Procedure

Up to this point in the unit, pupils have been learning about the parts of a circuit that produce electric current, carry it, or control it. With this problem, they will begin the study of various devices that use electric current. To introduce the problem, ask the pupils to name as many electrical heating appliances as they can. They will probably mention electric irons, toasters, coffee pots, stoves, heating pads, etc.

Now raise the question, "Where does the heat come from?" Usually the pupils will answer, "From the electric current." If they do not give this answer, ask further questions such as: "What must we do to get heat from the appliance?" (Turn it on, connect it, plug it in.) "What happens when we do this?" (The circuit is closed, current flows.) This line of questioning should bring out the desired answer. Then ask the pupils when they observed electric current being changed to heat. They should recall the short-circuit experiment (page 131) and the fuse experiment (page 133).

The pupils are now ready to read the first two paragraphs and do the experiment on page 138. Have them check their conclusions by reading and discussing the two paragraphs that follow. They should then examine the heating element in an electric iron or other appliance, using the pictures on page 139, and read to the end of the problem. Point out the fact that the word *element* in *heating element* means "part"; it does not refer to *chemical element.*

After the safety rules on page 139 have been studied, pupils may wish to make a complete list of all the rules given in the unit. The list can be made into a wall chart or taken home for discussion with parents. For additional activities, see *Things to Do*, page 155, Nos. 4 and 7.

Questions (Page 139)

1. The energy of the current is changed to heat energy when the current flows through a material that is not a good conductor. More energy is needed to make current flow through the poor conductor. This energy is changed to heat.
2. The heating elements of all electric heating appliances change the energy of electric current into heat energy.
3. They are made of copper, which is a good conductor.

How does electric current give us light? (Pages 140-142)

Concepts

1. When electric current flows through a poor conductor, the conductor gets so hot that it gives off light.
2. Some light is made with gases that glow when an electric current flows through them.

Information for the teacher

The common filament-type light bulb is also called an *incandescent* lamp. Besides neon, mercury vapor and helium are often used in advertising signs. Mercury vapor gives a bluish-green light, and helium gives a white light. The rays mentioned on page 142 are ultraviolet rays. For most purposes, the bluish-green light of mercury vapor is unpleasant. In a fluorescent lamp, the coating conceals this light and gives a white light much like sunlight.

Observation

Page 140: To examine the filament in an electric-light bulb.

Materials: Worn-out electric-light bulb that can be broken, cloth or paper.

Procedure

This problem is closely related to the preceding one. To introduce this problem, ask the pupils, "Did you ever try to remove a light bulb that had been lit for some time?" "What did you notice?" Then have the pupils recall what happened in the experiment with iron wire (page 138). Then say, "You felt the wire get hot. Did you notice anything else?" (The wire gave off a red glow.) Now ask, "How do you think we could use an electric current to get light?" (Use it to heat a wire white-hot.) After the discussion, have the pupils read down to the paragraph at the top of the second column on page 141. If possible, they should examine a light bulb as directed on that page. They should then read to the end of the problem and examine the pictures on page 141.

Questions (Page 142)

1. White-hot.
2. A fine wire used inside an electric bulb. Much energy is needed to make the current flow through it; this energy is changed to heat; the wire gets white-hot and gives light.
3. Copper is a good conductor; it would not get hot enough to give light.
4. It lasts for hundreds of hours before melting and gives very good light.
5. The carbon filament in the first electric-light bulb did not last long enough, and it did not give very much light.
6. When current flows through neon gas, the gas glows and gives light.
7. A lamp that gives light when an electric current flows through a small amount of mercury inside a glass tube and changes the mercury to a gas. The inside of the tube is coated with special materials. The gas gives off rays that make these materials glow.

How can we use electric current to make a magnet? (Pages 143-146)

Concepts

1. Electric current can be used to make a magnet.
   - *a*) An electromagnet is made when an electric current flows through a wire wound around a piece of iron or steel.
   - *b*) An electromagnet has force only so long as the electric current is flowing; its force can be controlled by turning the current on or off.
   - *c*) An electromagnet can be made stronger by increasing the number of turns of wire wound around the core and by increasing the current.
2. An electromagnet can make things move.

Experiments

PAGES 143-144: To make an electromagnet.

MATERIALS: Large nail or bolt, iron or steel tacks, two feet of cotton-covered copper wire, dry cell.

PAGE 144: To see what kinds of materials an electromagnet will attract.

MATERIALS: Same as for the experiment on pages 143-144. Also glass, cloth, tin, lead, rubber, wood.

PAGE 144: To see how the force of an electromagnet can be controlled.

MATERIALS: Same as for the experiment on pages 143-144. Also bar magnet or horseshoe magnet.

PAGE 145: To find out how the force of an electromagnet is made stronger.

MATERIALS: Same as for the experiment on pages 143-144. Also one additional dry cell.

Information for the teacher

Magnets such as the horseshoe magnet and the bar magnet are called *permanent* magnets. An electromagnet is a *temporary* magnet.

Pupils may ask how the wire wound around the nail can magnetize the nail, since the wire is insulated and they have just learned that electric current will not flow through the insulation on the wire. The electric current does not flow into the nail to magnetize it. The current flowing through the wire makes the wire a magnet. The magnetic force of the magnetized wire is able to act through the insulation, which is a non-magnetic material. The iron nail acts as a core, which increases the magnetic force of the coil of wire.

In the experiments with the electromagnet, use an iron rather than a steel nail or bolt if possible. Steel is used to make permanent magnets. A steel nail or bolt may retain enough magnetism to attract a few tacks even after the current is turned off. If you cannot obtain an iron nail or bolt, heat a steel nail or bolt red-hot in a flame. After the steel cools, it will have less tendency to retain magnetism.

Procedure

This problem, dealing with the electromagnet, develops the concepts essential to an understanding of the three problems that follow. To begin the problem, have the pupils read the first four paragraphs on page 143 and refer to the picture on page 142. The questions raised in the fourth paragraph should then be used to motivate the experiment. Before doing the experiment, pupils should recall experiences with magnets and the concepts developed in earlier science study. (Refer to *Discovering Our World, Book One*, Unit 6, and *Book Two*, Unit 2, pages 64-66.)

Now have the pupils do the experiment described and illustrated on pages 143-144. They should draw their conclusions and then read the second and third paragraphs on page 144, which lead them into the next experiment. Again have the pupils check their findings by reading the text down to the last paragraph in the first column on page 145. The experiment described and pictured on page 145 should now be performed and the results discussed. The pupils should now read the last paragraph of the unit and summarize the concepts developed in the problem. They should also look for electromagnets around their homes in preparation for the problems that follow.

Questions (Page 146)

1. A nail or bolt, some wire, and a dry cell.
2. Wind the wire around the nail or bolt; connect the ends of the wire to the dry cell.
3. Wind more turns of wire around the nail or bolt. Make the current stronger by connecting more than one dry cell.
4. *Like:* They will attract the same things. *Different:* The force of an electromagnet can be controlled by turning the current on or off. The force of the other magnets cannot be controlled.
5. Their force can be controlled. They can be made very strong. They make it possible for electric current to move things.

How does a telegraph work? (Pages 146-149)

Concepts

1. In a telegraph or other electrical device, the part that is moved by an electromagnet is called the *armature.*
2. The movement of the armature is controlled by opening and closing the circuit.

Experiment

Pages 147-148: To make a telegraph set and find out how it works.

Materials: Two pieces of soft wood, large nail, small nail, two feet of insulated copper wire, six screws, two strips from tin can (three quarters of an inch wide and four inches long), dry cell.

Information for the teacher

The code shown on page 148 is the International Code used for sending messages by radio. The Morse Code used by telegraphers consists of spaces as well as dots and dashes.

Procedure

In this problem, pupils are given an opportunity to apply and extend the concepts developed in the preceding problem. The telegraph set described and illustrated on pages 147-148 is not hard to make. A group of interested pupils may easily build it and then show the class how it is operated. The class should read and discuss pages 146-149. Pupils are not expected to learn the code given on page 148, but some may wish to use it in sending simple messages.

Two telegraph sets may be connected and messages sent from one to the other. Use two dry cells connected as shown in the picture on page 145. Connect one binding post of one set to a binding post of the other set, using an unbroken wire. Then connect the cells between the two remaining binding posts of the sets. To receive messages, hold the key of one set down while the key of the other set is operated. (In a real telegraph set, a switch is used to short-circuit the key.) For additional activities, see *Things to Do*, page 155, Nos. 6, 8, and 11.

Questions (Page 149)

1. The sounder clicks. The circuit is closed. Current flows through the electromagnet, which pulls down on the armature.
2. The sounder clicks again. The circuit is opened. Current no longer flows through the wire of the electromagnet, and so the armature springs away. It hits the nail above the armature, making a click.
3. By pushing the key down and letting it up quickly for a dot and holding it down a little longer for a dash.
4. No. The force of a bar magnet cannot be controlled to make the armature move.
5. Yes. Wherever something is moved by electric current, there is an electromagnet. Any part that is moved by an electromagnet is called an armature.

How does an electric bell ring? (Pages 149-151)

Concepts

1. An electric bell keeps on ringing as long as the push button is held down.
2. The spring and the contact point open and close the circuit as the armature moves back and forth.

Experiment

PAGES 149-150: To find out how an electric bell works.

MATERIALS: Electric bell, push button, dry cell.

Information for the teacher

As mentioned earlier in this unit, more than one dry cell may be needed to operate the electric bell. Connect the dry cells as shown in the picture on page 145.

Procedure

After studying the two preceding problems, pupils can easily understand how an electric bell works. The bell has an electromagnet and an armature just as a telegraph sounder has. The push button, like a telegraph key, is a kind of switch. The only new idea to be developed is how the contact point and the spring on the armature operate as a switch to open and close the circuit, keeping the bell ringing as long as the push button is held down.

To introduce the problem, let the pupils first examine and then operate an electric bell. They should use the pictures and follow the directions on pages 149-150. (The picture on page 136 shows how to connect the bell.) Then have them read the text to check their conclusions and find additional information. If an electric buzzer is available, it should also be examined and operated as suggested on page 151.

Questions (Page 151)

1. Electromagnet and armature.
2. Push button.
3. Holding the push button down closes the circuit. Electric current flows through the electromagnet, which pulls the armature toward it.
4. When current flows through the electromagnet, the armature is pulled away from the contact point. This opens the circuit. Current no longer flows through the electromagnet, and so the armature moves back to the contact point. The hammer is attached to the armature and moves back and forth with it.

How does an electric motor run? (Pages 151-154)

Concepts

1. An electromagnet has two poles, an N pole and an S pole, just as other magnets do.
2. An electric motor turns as the poles of an electromagnet are first attracted and then repelled by the poles of another magnet.

Experiments

PAGE 152: To find out whether an electromagnet has an N pole and an S pole.

MATERIALS: Bar magnet, wooden support, string, electromagnet, dry cell.

PAGES 152-153: To see how an electromagnet can turn a motor.

MATERIALS: Two bar magnets, support, string, electromagnet, dry cell.

PAGE 153: To observe how a motor runs.

MATERIALS: Toy electric motor, insulated copper wire, two dry cells.

Information for the teacher

PICTURE. PAGE 153. The man is using a jig saw. Next are a grinding wheel, a lathe, and a planer.

TEXT. The magnet surrounding the armature is called the *field magnet.* Current is carried to and from the electromagnets in the armature through sliding contacts called *brushes.* The brushes rub against the *commutator*, which is fastened to the shaft of the armature and turns with it. The commutator is connected to the armature in such a way that the poles of the electromagnets are reversed at just the right times to keep the armature turning. For more information about electric motors, see a high-school general science book or a physics text.

Procedure

This problem is intended primarily to show the importance of electric motors, which depend on electromagnets for their operation. At this grade level, pupils cannot be expected to master the details of how motors work. To begin the problem, have the pupils read page 151 and examine the picture. If a toy motor is available, let them find the electromagnets in the armature and also the electromagnet in the frame.

From earlier science study (*Discovering Our World, Book One*, Unit 6), the children should recall the three concepts listed on page 152. These should be discussed before the first experiment on that page is performed. After doing the experiment, pupils should read down to the next to last paragraph on that page to check their findings. They are now ready to do the next experiment on pages 152-153. (A similar experiment in *Discovering Our World, Book Two*, Unit 2, page 65, may be recalled.) The results should be checked and summarized by reading the first paragraph on page 153. Pupils should then connect a toy motor and operate it as suggested in the last paragraph. For an additional activity, see *Things to Do*, page 155, No. 13.

Questions (Page 154)

1. Electromagnet.

2. The armature would not turn because the electromagnets would not pull and push on the poles of the magnet in the frame.

3. The poles of the electromagnets must pull and push on the poles of the magnet in the frame in order to make the armature turn.

Questions to answer (Page 154)

Pictures. *Left.* No. Because the switch is open. *Right.* No. The covering is so worn that short circuits might occur.

1. To keep from being burned or even killed, and to prevent fire.

2. For light, heat, and running motors.

3. List may include: electric lights, irons, toasters, and other appliances, radios, telephones, telegraphs, streetcars, theaters, most industrial machinery, pumps, etc.

4. Power lines might break down or become short-circuited. Short circuits might melt a fuse.

5. Electric current can make things move. It takes force to move anything, and some kind of energy is needed to produce a force.

6. The wire to make sure there was no short circuit. The connections to see that the wire was bare and tightly fastened. The dry cell to be sure it could supply current. The switch to see whether it was closed. The motor to be sure that all parts worked so that current would flow through it.

7. By winding many turns of wire on the electromagnets and using a strong current.

8. The sun supplies heat that makes water evaporate. The water condenses and falls to earth. Gravity makes the water run downhill, supplying the force to moving water. They both help make the wind blow, and the force of the wind will turn windmills. These forces turn generators that produce electric current.

Things to do (Page 155)

1. Group or individual activity. Steam or moving water is probably used to run the generators.

2. The boxlike transformer on a pole is a distribution transformer. It decreases the voltage of the current for use in your home.

3. Any garage will have a generator or some other source of electrical energy to charge storage batteries.

4. Yes. Three wires are needed. They are larger than wires used in lighting circuits. Yes. Two of the three wires have special fuses. These are cartridge fuses (cylindrical) instead of the usual plug type.

5-6. Individual or group activities.

7. The pad is insulated with a flexible material such as asbestos. The heating element is made of a very long wire.

8. Individual report. See encyclopedias for articles on Cyrus Field or submarine telegraph.

9. Consult the local electric company or an electric bill.

10. A rheostat is usually made of a coil of wire. Sometimes it is made of carbon disks or of rods in salt water. It is used to control the

amount of current in a circuit. By moving the handle, lights can be dimmed, motors slowed down, etc.

11. Individual activity. See encyclopedias.
12. Individual or group activity.
13. All generators have electromagnets in their armatures. All except a magneto have electromagnets in their frames. (A magneto has a permanent magnet instead.) All generators have armatures.

UNIT 6. *How Do We Use Light?*

Purpose and scope

This unit deals with subject matter especially close to the pupils' everyday life. Although the pupils have often seen the things that light does, the science principles that explain these things will probably be startlingly new. However, as in the Sound unit, there is abundant opportunity to demonstrate these principles.

Of particularly personal interest to the pupils are the pages dealing with lenses and those dealing with the eyes. These pages are concerned with the structure and working of the eye, mechanical aids to vision, and the care of the eyes. Note especially the twelve safety rules for the care of the eyes on page 180. The teacher can render a most valuable service in driving home the lessons of conservation of sight and in helping children whose eyes may need care.

This unit makes use of concepts developed in earlier units, as indicated in *Science Background* below. Pupils should already know that when anything gets hot enough, it gives off light. It may burn if there is oxygen present. The unit also prepares for the discussion of light from the heavenly bodies treated in the next unit. In fact, this unit on light is prerequisite to certain parts of the unit on the universe.

Science background

All Around Us: Unit 3, Sun, Wind, and Weather

Discovering Our World, Book One: Unit 4, Why Do We Have Days and Nights? Unit 5, What Can We See in the Sky at Night?

Discovering Our World, Book Two: Unit 5, What Are Things Made Of? Unit 6, How Do We Control Fire?

Discovering Our World, Book Three: Unit 5, How Do We Use Electric Current?

General concepts

1. All our light comes from some material that is heated until it glows or burns with a flame.
2. Light travels at very high speed, in a straight line, and outward in all directions from its source.
3. We see only objects that give off light or reflect light.
4. Light is reflected by most materials.
5. Light is absorbed by many materials.
6. Light can pass through some materials but not through others.
7. An object is seen in a mirror because light travels from the object to the mirror and is reflected back to the observer.
8. Light travels away from the mirror on the same slant at which it strikes the mirror but in the opposite direction.
9. Light is bent when it travels through a lens.
10. Lenses can be used to help us see things that are very small or far away.
11. Different parts of the eye work together so that we can see.
12. The eyes must be properly cared for.
13. The color of an object is caused by the way in which it reflects certain light rays and absorbs others.

Introducing the unit (Page 157)

Information for the teacher

Picture. Page 156. A night photograph taken by flash bulb. It can be used with the text on page 157 and later with the problem on reflection, pages 168-171.

Procedure

This unit may be introduced by asking the question that opens the introductory section. During the discussion that follows, the pictures on pages 156 and 157 should be used. (Some of the pupils may know enough about photography to know that the night picture of the deer was taken by flashlight photography.) The discussion should bring out the fact that we use light all the time we are awake. The difference between artificial light and daylight should also be pointed out.

Then have the pupils read the second paragraph. Discuss the questions and ask the children for possible explanations. Write the questions on the board with any explanations that have been made. As the unit proceeds, the children should refer to these answers, correct them if necessary, and fill in where they offered no explanation.

Where do we get light? (Pages 157-160)

Concepts

1. All our light comes from some material that is heated until it glows or burns with a flame.
2. People have used many ways to get light.

Procedure

Begin this problem by asking the children to think of as many ways as they can that are used or have been used to get artificial light. They will probably mention fire, candles, electric lights, kerosene or gasoline lamps if they live in the country or visit camps or country places in summer, and possibly neon signs. They should recall the problem on electric lighting in Unit 5. Some may have seen gas jets. As the children name the different ways, list them on the board. Ask them which ways they think were used first.

The pupils will probably be unable to name all the ways and to be sure which way was used first. Have them read the problem, look at the pictures (also those on pages 140-141), and make individual lists of the ways of lighting in the order of development. After the lists are completed, the pupils should discuss the various items. These two questions should form the basis for the discussion: (1) What were the disadvantages of each way of producing light? (2) How was each of the ways an advantage over the previous ways? Following the discussion, make the necessary additions and changes in the list on the board. Pictures of various types of lighting can be collected and made into charts to add interest to the problem.

Questions (Page 160)

1. Blazing sticks, torches made of pine knots, greased sticks, etc.; burning oil in a dish, and later a wick dipped in the oil; wax candles; kerosene in lamps with wicks and glass chimneys; gas made from coal, and natural gas; electric current in a carbon, and later a tungsten filament in a bulb; fluorescent lamps.
2. The use of fire for heat and light; how to get oil from plants and animals; the use of a wick to control the amount of fire; how to make candles; the discovery of oil in the earth and how to make kerosene from it; how to get gas from burning coal and from the earth; Edison's invention of the light bulb using a carbon filament; the substitution of tungsten for carbon in the filament of a light bulb; the use of mercury vapor to make fluorescent lamps.
3. A kerosene lamp or a candle gives light by burning materials. An electric lamp glows without burning materials.
4. An electric lamp is clean, bright, and lasts a long time. A kerosene lamp is not very bright, must be filled, cleaned, and have the wick trimmed frequently. It is also more dangerous to use.

How does light travel? (Pages 160-163)

Concepts

1. Light travels at the speed of about 186,000 miles a second.
2. Light travels in a straight line.
3. Light travels outward in all directions from its source.

Experiments

PAGE 162: To show that light travels in a straight line.

MATERIALS: Two pieces of cardboard, electric lamp, large piece of brown wrapping paper, ball or globe, flashlight.

Information for the teacher

Galileo, whose full name was Galileo Galilei, lived from 1564 to 1642. The Danish scientist who determined the speed of light about the year 1676 was Olaf Roemer.

Procedure

This problem can be started by asking the pupils how long they think it takes the light from the sun to reach us. They should recall that the sun is about 93 million miles away from the earth. Pupils will probably be unable to state the exact or even the approximate time. After the discussion, have them read pages 160 and 161 to see how one scientist tried to find out the speed of light and to learn what the speed of light now is known to be.

As suggested in *Questions to Answer*, page 185, No. 4, pupils can now figure out how long it takes light to reach us from the sun. Have them use 186,000 miles per second as the speed of light, since the arithmetic is easier. The answer should be about 8⅓ minutes.

Now the pupils are ready to do several experiments to show that light travels in a straight line as it travels through air. Have the pupils do the experiments described and pictured on pages 162 and 163. After each experiment, pupils should answer the question: "What does this experiment show about how light travels?" When all the experiments have been done, ask, "How are the experiments all alike?" (They all show that light travels in a straight line.) Then have the pupils read page 163, and ask them what else they have learned about how light travels. (Light travels outward in all directions from anything that glows.)

Questions (Page 163)

1. Light travels so fast that the second or two that the men took to open the shutters spoiled the experiment.
2. (*c*) See the experiment on page 162.
3. Divide 240,000 by 186,284. Answer: 1.288 or a little more than one and a quarter seconds.
4. It travels very fast, in a straight line, and outward in all directions.
5. Because light travels in a straight line. It cannot go through or around things.

When can we see things? (Pages 164-167)

Concepts

1. We see only objects that give off light or reflect light.
2. Light is reflected by most materials.
   a) Smooth surfaces reflect more light than rough surfaces.
   b) Light-colored materials reflect more light than dark-colored materials.
3. Light is absorbed by many materials. Dark-colored materials absorb more light than light-colored materials.
4. Light can pass through some materials but not through others.
   a) Light cannot pass through opaque materials.
   b) Light can pass through transparent and translucent materials.
   c) We can see clearly through transparent but not through translucent materials.

Experiments

PAGES 164-165: To find out how smooth and rough surfaces reflect light.

MATERIALS: Mirror, pan of water.

Page 165: To see that light-colored materials reflect more light than dark-colored materials.

Materials: Large piece of brown wrapping paper, piece of glossy white cardboard, blotting paper, white cloth, dark cloth.

Information for the teacher

Pictures. Page 164. The white stripes are made with luminescent paint.

Page 165. Not a perfect reflection, as the water is rough. On page 156 the water was smooth so that the deer's reflection is almost perfect.

Page 167. The solid panels on either side of the door, the ceiling, the floor, and the chairs are opaque. The glass-brick walls are translucent. The glass doors are transparent.

Text. The scattering of light mentioned and illustrated on page 165 is called *diffusion*.

Procedure

One way to start this problem is to ask the pupils the question stated in the problem title. Then ask them to read and discuss the first two paragraphs. They may wish to carry out the activity suggested in the second paragraph.

Next ask about things that do not glow. Have the pupils do the experiments on pages 164-165. They should then discuss their observations, using the questions in the text as a guide to the discussion. Recall the meaning of *reflect* and develop the meaning of *absorb*. Lead the children to this generalization: We can see a thing when it reflects light to our eyes. Make clear that materials differ in the way in which they reflect or absorb light. Then let the pupils read the text down to the last paragraph in the first column on page 166. Have them examine the picture on page 165 and answer the question under it. An additional activity is suggested in *Things to Do*, page 185, No. 2.

The rest of the problem deals with another aspect of materials with respect to light. The next paragraph on page 166 and the activity suggested in the picture below it should be used to start discussion. At this point, pupils may also wish to carry out the activity given in *Things to Do*, page 185, No. 5. The collection of opaque, transparent, and translucent materials should be tested with the flashlight. Each material should then be put in the proper group. Now let the children read the next three paragraphs to check their findings. The picture on page 167 should then be examined and the question under it answered. As a summary of important concepts, have the pupils read the last two paragraphs.

Questions (Page 167)

1. They glow with their own light.
2. It reflects light to your eyes.
3. The mirror is smoother. It will reflect almost all the light that strikes it.
4. Water reflects more light than the rougher, dry surface.
5. You can see only when light travels to your eyes. The light may come from something that glows or it may be reflected.
6. You cannot see through an opaque material such as wood, metal, etc.; but you can see through a transparent material such as air, window glass, etc. Translucent materials such as thin paper and cloth will let light through even though you cannot see through them.
7. Some light is absorbed by the dirt.

Why can you see yourself in a mirror? (Pages 168-171)

Concepts

1. An object is seen in a mirror because light travels from the object to the mirror and is reflected back to the observer.
2. Light travels away from the mirror on the same slant at which it strikes the mirror.

Experiments

Pages 169-170: To see how light is reflected by a mirror.

Materials: Rubber ball, mirror.

Pages 170-171: To make a periscope and to see how it changes the direction of light.

Materials: Cardboard tube or narrow wooden box, two mirrors, knife for cutting tube or saw for cutting box, nails for mirrors to rest on.

Information for the teacher

The principle developed in this problem is stated by scientists in this way: *The angle of reflection is equal to the angle of incidence.* Both of these angles are measured from a line perpendicular to the surface at the point where light strikes the surface and is reflected. Although this principle applies to reflection generally, it is here applied only to flat, or *plane,* mirrors. Curved mirrors (concave and convex) are too difficult to explain at this level.

Periscopes in submarines use prisms to reflect light. The inner surfaces of the prisms reflect light just as a mirror does. This phenomenon is called *internal reflection.*

Procedure

To begin this problem, ask the pupils to tell anything they have noticed about how a mirror works. If possible, there should be several small mirrors in the room so that the pupils may see a mirror as they describe their observations. Write their observations on the board. Then have the pupils examine the pictures on pages 168, 169, and 170 and do the experiments.

From the experiments, they should see that (1) if a person stands straight in front of a mirror, the light travels as shown in the picture on page 168; and (2) when light strikes a mirror at a slant, it leaves the mirror at the same slant, as illustrated by the experiment with the ball. Pupils may make drawings on the board to show the path of light to and from mirrors set at different angles. If it is a sunny day, they may reflect light to various parts of the room by changing the angle of the mirror. Have the pupils read the text down to the second paragraph on page 170 to check their conclusions.

At this point, the teacher may ask for volunteers to make a periscope to use in the next lesson. They can use the text on page 170 and the picture on page 171 as a guide. In making the periscope, the pupils should drive small nails in from the outside for the mirrors to rest on at the points desired to make the proper angles. In the lesson on the periscope, ask the children who made it to show how it is constructed and to tell how it works. Be sure that all the children have an opportunity to look through it and understand it. Pupils will enjoy using the periscopes to see around corners and out of windows. The pupils may then read to the end of the problem to find out more about the periscope. For additional activities, see *Things to Do,* page 185, Nos. 4, 6, 8, and 12.

Questions (Page 171)

1. Directly in front. Light travels in a straight line from you to the mirror and back to your eyes.
2. Light travels from the tree to the water and then is reflected from the water to your eyes.
3. It will be wavy and less bright and clear.
4. Place it so that light from a window will be reflected toward the corner.
5. Light will travel at a slant from you to the mirror, then be reflected at the same slant in the opposite direction and not back to your eyes.

What do lenses do to light? (Pages 171-174)

Concepts

1. Light is bent when it travels through a lens.
2. The bending of light that travels from an object through a lens changes the apparent position or size of the object.

Experiments

PAGES 171-172: To show that light is bent when it passes through a lens.

MATERIALS: Reading glass, white paper, support for reading glass, candle.

PAGES 172-174: To show how light is focused by a lens.

MATERIALS: Reading glass, candle, white paper, support for reading glass.

PAGE 173: To observe how a slide projector projects slides.

MATERIALS: Slide projector, slides, screen or white wall.

Information for the teacher

When light traveling through one medium (air, for example) strikes another medium (water, glass, etc.) at an angle, the light is bent. This bending of light is called *refraction*. The amount which the light is bent depends on the density of the medium and the angle at which the light strikes the medium. The denser the medium that the light is entering, the more the rays are bent, or *refracted*. The greater the angle at which the light enters the medium, the more the light is bent. Light entering a denser medium is bent toward an imaginary perpendicular line that passes through the center of the medium. Light emerging from the other side, when the two surfaces of the medium are parallel, is bent away from the perpendicular so that the emerging ray is parallel to the position it had when it entered the medium. The light that strikes the new medium at right angles is not bent. It passes straight through but is slowed down.

Ordinary window glass does bend the light somewhat but not so much as plate glass, which is much thicker. A poor grade of window glass has a surface that is not perfectly smooth so that the rays are bent differently in different parts of the glass. This makes objects seen through the window look wavy. Light rays entering or leaving water at an angle are bent. Fish, stones, or other objects seen in the water seem to be nearer the surface than they are, because light rays coming from them to your eyes are bent.

Lenses make use of the principles of refraction. Parallel rays of light striking the lens enter the lens at a slant because the lens is curved. So the light is bent. A *convex* lens is thicker at the center than it is at the edges. A *concave* lens is thicker at the edges than at the center. A *double-convex* lens (curved outward on both sides), such as the one in a reading glass, is the type used in the experiments in this problem. Rays of light passing through this type of lens are bent toward the center. Those toward the outside are bent more because the curve of the lens is greater at the outside and increases the angle at which the light enters the lens.

Procedure

To start this problem, ask the children what they have already learned about lenses. They should recall from Unit 4 that a lens is a curved piece of glass. They will probably remember the use of lenses in the microscope. Most children will have looked through magnifying glasses, and some may have looked through telescopes. The children who wear glasses may know that they are wearing lenses. Lead the discussion to the point where the children wonder what lenses do to light that makes it possible to use them as we do. Then suggest that they carry out some experiments to find the answer to this question.

In doing the experiments with lenses, the children should follow the directions given in the text and study the pictures on pages 172-173. From these experiments, it may be seen how a lens bends light and how this fact is used in making lenses. After doing the experiments, these pages (up to the second paragraph on page 173) may be read again for explanation of what the pupils have seen.

Then the pupils should read the rest of the problem and do the experiment to find out how different devices make use of lenses. If a camera and a slide projector are available, the parts may be examined. Children in the class who wear glasses may be able to tell what their glasses do for them.

For additional activities, see *Things to Do*, page 185, Nos. 3, 7, 8, and 9.

Questions (Page 174)

1. Curved outward on both sides; thicker in the middle than at the edge.
2. It bends the light.
3. The picture is upside down, and either larger or smaller.
4. Closer.
5. So that the light will come to a focus on the film. You cannot move the film, and so you must move the lens to get a clear picture.

How do we see things that are very small or far away? (Pages 175-177)

Concept

Lenses can be used to help us see things that are very small or far away.

Observation

Page 175: To use a magnifying glass.
Materials: Magnifying glass, leaf.

Information for the teacher

Pictures. Page 175. The boys are looking at some pond water. They might see many kinds of green or blue-green algae and tiny water animals. The little animal on the left-hand side is *Cyclops*, a microscopic crustacean found in fresh water. It gets its name from its single eye. The center picture is the green alga, *Spirogyra*. The other is also a green alga called *Volvox*. Both of these are commonly found in fresh water.

Page 176. There have been many magazine and newspaper articles describing the making of the giant lens for the telescope at Mount Palomar. These may be consulted for pictures and further details.

Text. The microscope referred to in the text and the one in the picture on page 175 are *compound* microscopes, that is, having two lenses. A simple microscope has only one lens; it is really just a magnifying glass mounted so that it can be focused. The kind of telescope having two different lenses, such as the one at Yerkes Observatory, is called a *refracting* telescope. A third kind of telescope, using a spherical mirror and a correcting lens, is called the Schmidt telescope.

Procedure

The discussion at the beginning of the previous problem should have brought out the children's general experiences with lenses. If a compound microscope is available, the pupils should have an opportunity to examine it and to look at objects, such as a plant leaf, a bee's leg, or, as suggested by the picture on page 175, the tiny plants and animals found in water. If any pupil has a small telescope, ask him to bring it to school so that it can be examined by others. A pair of field glasses should also be provided for pupils, if possible, so that they may see the effect of lenses. After providing as many experiences as possible with lenses, have the pupils read the problem for additional information. The part on the telescope may be used as motivation for the next unit, What Is the Universe Like? For an additional activity to enrich this problem, see *Things to Do*, page 185, No. 1.

Questions (Page 177)

1. Scientists could then see and study very tiny plants and animals, some of which cause disease.
2. One kind has two lenses, one lens thicker in the middle than at the edge, the other lens thicker at the edges; another kind, the reflecting telescope, has only one lens and two different mirrors.
3. A microscope may have two lenses, each like a reading glass.

How do we see things? (Pages 177-180)

Concepts

1. Different parts of the eye work together so that we can see.
   - *a*) Light enters the eye through the pupil, whose size is controlled by the iris.
   - *b*) Light travels from the objects through the lens of the eye, which makes a picture of the object on the lining, or retina, of the eye.
   - *c*) Nerves in the retina carry messages to the brain, where the picture is interpreted.
2. The eyes must be properly cared for.

Observation

Pages 177-178: To observe the outer structure of the eye.
Material: Mirror.

Information for the teacher

Other important parts of the eye: *cornea*, transparent membrane (resembling a watch crystal) on the front of the eyeball; *conjunctiva*, thin mucous coating protecting the cornea; *aqueous humor*, clear liquid found in the space behind the cornea; *vitreous humor*, clear jelly-like substance filling the space between the lens and the retina; *sclerotic coat*, white, fibrous, protective coat covering the eyeball, lending form and shape to the eye; *choroid coat*, middle coat or membrane between the sclerotic coat and retina; *optic nerve*, carries the images to the brain; *blind spot*, spot at which the optic nerve leaves the eye and therefore does not detect light.

Pupils may wonder why we do not see things upside down. The image on the retina is upside down; but in some way not yet understood, the brain interprets the image so that we see things right side up. The eye is focused by the bulging or flattening out of the lens. It bulges out when we look at close objects and flattens when we are looking at far-off ones. These adjustments are automatic and are made unconsciously.

Procedure

This problem on the eyes is probably the most important one in the unit from the point of view of close relation to the pupils' daily lives. To start the problem, have each pupil look closely at another's eyes and compare them with the picture on page 178 to learn the outer parts of the eye. Also have pupils do the experiment suggested on page 178. Then they should read page 177 through the first paragraph on page 179 to find out more about the parts of the eye and how they work.

The rest of the problem is extremely important. Have the children read the text, look at the picture on page 179, and answer the question under it. The pupils should then discuss each safety rule on page 180, so that everyone understands the reasons for it. Pupils should check each other in the schoolroom to see that the rules are being observed. They should show the rules to their parents and discuss them at home. For additional activities, see *Things to Do*, page 185, Nos. 10 and 13.

Questions (Page 180)

1. *Pupil:* lets light into the eye; *retina:* receives the light. It has many tiny nerves that carry messages to the brain. *Iris:* can make the pupil larger or smaller to let the right amount of light in. *Muscles:* hold the eyeball in its socket and make it move so that you can see up, down, to the sides, etc. *Socket:* pocket in bones of skull that holds eyeball and helps protect it. *Lens:* bends the light and brings it to a focus on the retina.
2. Working your eyes too hard or too long; using them in light that is too bright or too dim; letting light shine directly into them.
3. Answer should include the safety rules, page 180.

Why do things have different colors? (Pages 181-184)

Concepts

1. The color of an object is caused by the way in which it reflects certain light rays and absorbs others.
2. Sunlight is a mixture of light rays of many colors.
3. The colors of sunlight are separated when sunlight passes through a prism.
4. White is not a color; it is a mixture of all the colors.
5. Black is not a color; it is lack of color.

Experiments and observations

PAGE 181: To observe the separation of colors formed when sunlight passes through a glass prism.

MATERIALS: Prism, piece of white paper.

PAGE 182: To show that white is a mixture of colors.

MATERIALS: Circle of cardboard, red, blue, and green crayons or colored paper, top or toy motor with place for attaching color wheel.

PAGES 183-184: To show that the color of an object is caused by the light it reflects.

MATERIALS: Piece of brown wrapping paper big enough to cover a window, white paper, red, blue, and green glass or cellophane.

Information for the teacher

The band of color seen when light passes through a prism is called the *spectrum*. The spectrum is usually said to have seven colors: violet, indigo, blue, green, yellow, orange, and red. Light travels in waves of various lengths. Each kind of color light has its own wave length. Violet has the shortest wave length and red the longest. The wave lengths of the other colors are in between. Light rays are bent when they pass into glass. The shortest waves are bent more than the longest. Since each kind of light is bent differently, the result is the bands of the different colors on the paper.

Procedure

Introduce this problem by having the children look at all the colored objects that they can see in the room or out of the window. Ask the pupils why they think these objects have color. Many will probably say, "Because they are painted or colored with paints, crayons, etc." This is true, of course. But the real questions to be answered are why the paints and dyes have different colors and why a given color does not always look the same. List their reasons and any unanswered questions on the board. Then suggest that they do some experiments to see whether their reasons are correct and to answer their questions.

Have the pupils do the experiment with the prisms on page 181. Let them discuss their observations, using the questions in the second column as a basis for the discussion. Then do the color-wheel experiment to find the answer to the last question. After doing the experiments, the pupils should read the text up to the second paragraph on page 183 for explanation of what they observed.

The rest of the problem relates what they have learned about white light to the reasons why things have different colors. After the pupils have done the experiment with the colored glass or cellophane and discussed it, have them read the text from the second paragraph on page 183 to the end of the problem. Then look back at the questions asked at the beginning of the problem and answer any that were left unanswered. After doing the experiments and reading the text, children should be able to explain why paints and dyes have different colors. The materials from which they are made absorb colors differently. When something is painted, colored, or dyed, some of the material that reflects the desired color is transferred to the thing to be colored. For an additional activity, see *Things to Do*, page 185, No. 11.

Questions (Page 184)

1. It bends each color in white light a different amount.
2. The cover absorbs all other colors but reflects blue.
3. The glass lets only the red light through.
4. White sunlight and many tiny drops of water floating in the air. The separation of the white light by the raindrops acting like a prism causes the rainbow.
5. Mixing all colors of light gives white. Separating white sunlight with a prism gives all colors.

Questions to answer (Pages 184-185)

1. Dirt makes the window less transparent; so less light passes through it.
2. In a microscope, lenses make very tiny things large enough to see and study. In a telescope or field glasses, they make things that are far away seem closer. Cameras, periscopes, eyeglasses, and other instruments using lenses are very helpful.
3. If white or very light-colored costumes are used, shining a red light on them will make them reflect red, blue light will make them seem blue, etc.
4. Divide 93 million by 186,000. Answer: 500 seconds, or 8⅓ minutes.

5. In sunlight, the cloth absorbs all colors but red. Red is reflected, and so the cloth looks red. Green glass absorbs all colors but green. Green light has no red in it, and so the cloth looks black. Black is a lack of color.

6. A well-lighted room will have large windows, shades to prevent glare from bright sunlight, light-colored walls to reflect light into darker corners, sufficient artificial lighting for dark days, desks placed so that neither shadows nor glare will fall across them, etc.

7. By having plenty of light without glare and sitting in such a position that the book or paper is not shadowed.

8. Each has one lens that bends light and brings it to a focus. A picture is then made behind the lens. In your eye, the picture is made on the retina; in a camera, it is made on the film. The shutters of a camera can be set to let in the right amount of light. In your eye, the iris changes the size of the pupil to do the same thing.

Yes. Because there is only one lens.

9. Black absorbs all colors and reflects none; so it is a lack of color. White reflects all colors; so it is a mixture of all colors.

Things to do (Page 185)

1. Individual report. This activity may be combined with the suggested visit to see a telescope for the next unit. See *Things to Do*, page 213, No. 5.

2. Several kinds are used. Some are cut to reflect almost all light that strikes them. Some are made of glass balls, polished metal, or prisms.

3. List might include: eyeglasses, binoculars, microscope, telescope, camera, spotlight, flashlight, headlight, stereoscope, moving picture or slide projector, periscope, etc.

4. Doctors use concave mirrors to reflect light into the mouth and throat. Dental mirrors are concave; they magnify the teeth.

5. Group activity.

6. Plate glass is placed on heated tables. A diluted compound of silver nitrate, ammonia, and tartaric acid is poured over the glass. The heat helps the silver stick to the glass. When dry, the back is shellacked and then painted.

7. Concave, convex, double-concave, double-convex, concavo-convex.

8. They have a lens in front and a reflector behind the source of light, both of which help to direct the light to the right place on the road.

9. With a thicker lens, the focus is closer. With a thinner lens, the focus is farther away.

10. *Oyster:* no eyes. *Mole:* almost blind. *Fly:* compound eye made up of many parts. *Bird:* highly developed eye; can see at great distances. *Cat:* cannot see in absolute darkness but needs less light than any other common animal. *Owl:* sees poorly in daylight but well at night; immovable eyeball. *Whale:* eyes about size of a grapefruit; immovable eyeball.

11-12. Individual or group activities.

13. The Snellen chart is commonly used.

UNIT 7 ◦ *What Is the Universe Like?*

Purpose and scope

This unit continues the study of the earth and its relation to other parts of the universe begun in earlier books of the *Basic Studies in Science* program. *Discovering Our World, Book One*, Unit 4, presented the sun as our source of light and heat and also explained some of the effects of the earth's movements. Unit 5 dealt with stars, some of the constellations, the moon, the planets, and meteors. *Book Two*, Unit 2, took up the sun as a source of energy and also introduced the concept of gravity. Unit 8 told how green plants make food by using the sun's energy. *Book Three*, Unit 2, explained how changes take place in the earth's atmosphere. Unit 3 discussed the changes continually being made in the earth's surface.

Having studied all these units, pupils are now ready to make a broad survey of the universe as whole and of the earth's place in the universe. The increased maturity of the children and their background information about the energy and materials essential for life enable them to grasp ideas not comprehensible before. When they finish this unit, pupils should have a feeling for the vast expanse of the universe as well as an understanding of the earth's place in the universe. The unit offers many excellent opportunities to stress the value of the scientific attitude and to show how such an attitude affects our thinking and behavior.

Science background

Look and Learn: Unit 3, Days and Days

All Around Us: Unit 3, Sun, Wind, and Weather

How Do We Know?: Unit 2, Land and Water

Discovering Our World, Book One: Unit 4, Why Do We Have Days and Nights? Unit 5, What Can We See in the Sky at Night?

Discovering Our World, Book Two: Unit 1, How Do Living Things Help and Harm Each Other? Unit 2, What Makes Things Move? Unit 6, How Do We Control Fire? Unit 8, Where Does All the Food of the World Come From?

Discovering Our World, Book Three: Unit 2, Why Does the Weather Change? Unit 5, How Do We Use Electric Current? Unit 6, How Do We Use Light?

General concepts

1. The solar system is made up of the sun, the planets and their moons, planetoids, and comets.
2. The universe is made up of everything in the sky, including the solar system.
3. We need the sun for heat, light, food, and energy.
4. The earth and the other things of the solar system travel around the sun at terrific speed, each held in its own orbit and moving in a regular and exactly predictable manner.
5. The planets vary in size, distance from the sun, speed of revolution, number of moons, etc.
6. No life is definitely known of on any planet except the earth.
7. Comets are made up of gases and little bits of solids.
8. An eclipse of the sun is caused by the moon passing between the earth and the sun; an eclipse of the moon is caused by the earth passing between the moon and the sun.
9. Distances between the stars are so vast that scientists measure them in light-years.
10. There are billions of stars in the universe.

Introducing the unit (Pages 187-189)

Concepts

1. The solar system is made up of the sun, the planets and their moons, planetoids, and comets.
2. The universe is made up of everything in the sky, including the solar system.

Procedure

Introduce this unit by asking the pupils to recall what they already know about the things that they see in the sky at night. From their own experience and from Unit 5, *Book One*, they should be able to name most of the parts of the universe to be studied in this unit. List the items on the board. As the unit progresses, the name of the group or system to which each belongs can be written beside the item. At the end of the unit, they can be rearranged to make a diagram showing the relation of the parts of the universe to each other. The pictures on pages 186-187 should be used to bring out the idea of the vast expanse of the universe. The members of our solar system are but few in comparison with the countless numbers of objects in the universe of which the solar system is a tiny part. The picture is, of course, idealized to bring out this point and to show how the solar system would appear if viewed from some place beyond it.

After the discussion, have the pupils read pages 187-189 and check the list on the board. The story of Columbus and the eclipse may start a discussion of eclipses that the children have seen. If any have had this experience, let them tell about it; but defer attempts to explain eclipses until the class comes to that problem in the unit. This section may also lead to a discussion of ways in which people have used the sun and stars and how we use them today. Pupils should recall Units 4 and 5, *Book One*, and think of other situations from their own experiences or from stories.

How does the sun help us? (Pages 189-193)

Concept

We need the sun for heat, light, food, and energy.

Procedure

Throughout the *Discovering Our World* series, the importance of the sun has frequently been mentioned. This problem brings together many of the previously taught concepts by telling an imaginary story of what would happen if the sun stopped shining. To introduce this problem, have the pupils read and discuss the first paragraph on page 189, using the picture on pages 188-189. The discussion should bring out the fact that although the distance to the sun is great, it is really very small compared with other distances in the universe.

Now ask the pupils to think of as many things as they can that would happen on the earth if the sun suddenly stopped shining. Have them explain their answers and write the answers and explanations on the board. Then let the children read the story and look at the pictures. They should compare the ideas in the text with the answers and explanations that they gave.

Questions (Page 193)

1. There would be no heat or light. Without these, no plants could live to supply food. Without plants, no animals could live. All water would be frozen. There would be no wind. So nothing could be moved by water or wind. No coal or oil could have been formed, and so there would be no energy from coal or oil.

2. Since the sun is the source of most of the energy we use, the list should include the ways in which we need and use energy.

3. No. Scientists tell us it will go on for millions and millions of years.

4. The energy in your muscles comes from the food you eat. All the food in the world comes from green plants, which use the energy of the sun to make food.

How do the planets move in the solar system? (Pages 194-197)

Concepts

1. The earth and the other things in the solar system travel around the sun at terrific speed.
2. Each of these is held in its own orbit by opposing forces.
3. The movements of the solar system are regular and exactly predictable.

Experiment

Page 195: To show how the earth stays in its orbit.

Materials: Ball, strong rubber band (or piece of elastic).

Information for the teacher

The force that makes any whirling object pull away from the center around which it whirls is called *centrifugal force*. Farm children will be familiar with the use of this principle in cream separators. Or the pupils may have seen a machine at a fair or carnival on which small cars move out from the center as the machine whirls.

There are about 1100 planetoids, varying in diameter from 20 to 300 miles. Scientists think that these planetoids may be pieces of a big planet that once traveled around the sun between Mars and Jupiter. Possibly this big planet met with an accident of some kind that broke it into pieces.

Procedure

The pupils already know that the earth and the other planets travel around the sun. Have them recall this fact and then read and discuss the text down to the experiment on page 195, using the picture on page 194. Now let the pupils do the experiment described and illustrated on page 195. After doing the experiment, they should check their findings by reading the text down to the third paragraph on page 196. They should then read to the end of the problem and examine the picture on page 197.

Questions (Page 197)

1. The sun.
2. They reflect the sun's light.
3. As it travels around the sun, a force pulls it away. An equal force pulls it toward the sun.
4. All travel around the sun in the same direction; each stays in its own orbit; most have one or more moons traveling in their own orbits with the planets; none have light of their own but reflect the sun's light; each turns on its own axis.
5. *Orbit:* path of a planet around the sun. *Axis:* imaginary line through a planet on which it rotates. Each planet has an axis on which it rotates. *Gravity:* the force that holds everything to the earth and keeps the planets in their positions in the solar system by pulling them toward the sun as the other force (centrifugal) is pulling them away. *Solar system:* the sun, the planets and their moons, and other things that revolve around it. Solar system is part of the universe; is 7½ billion miles across.

What have scientists learned about the planets? (Pages 198-204)

Concepts

1. The planets vary in size, distance from the sun, speed of revolution, number of moons, etc.
2. No life is definitely known on any planet except the earth.

Information for the teacher

Pictures. Pages 200-201. The stars in the constellation Leo seem to have moved because the earth is moving in its orbit around the sun. This makes the stars appear in a different position. Some that are visible at one time of year may be invisible at other times. We are not conscious of the movement of the earth. It is the stars that appear to move.

The planets are moving in their orbits around the sun. They have changed their positions in the two weeks that have elapsed between the two pictures. The planets themselves have moved because the distances between them have changed. Mars has moved nearer to Venus, and Mercury has moved farther away from Venus. This change of distance occurs because the planets travel at different speeds.

Page 204. From this "bedspring" aerial on a hilltop in New Jersey, a radar beam was directed at the moon, January 10, 1946. Less than two and one-half seconds later sensitive instruments received a response. Traveling at a speed of 186,000 miles a second, radar waves hit the moon and bounced back like an echo.

Text. Magazines such as *Junior Natural History* and *Nature Magazine* (see Bibliography) are excellent to consult to find out what planets are visible each month and how to locate them. Maps and interesting information are given.

Procedure

The problem may be introduced by asking the pupils to name all the planets they can think of. Write the names on the board. Then ask the children to tell anything that they know about the planets. They should recall what they learned in *Discovering Our World, Book One*, Unit 5. If they have read anything about planets in magazines and newspapers, they can contribute this information, too.

Now have the class read down to the first paragraph on page 202. The pupils should answer the questions asked in the second paragraph on page 198. This will review the relation of air and water to living things. On page 199, the discussion of seasons on Mars will afford a review of the general causes of seasons taught in *Discovering Our World, Book One*, Unit 4. Be sure that the children examine the pictures on pages 200 and 201 and answer the questions in the legend on page 201. From *Discovering Our World, Book One*, Unit 5, have the pupils recall or do again the experiment with the umbrella and globe on page 122 of that book. This will help them understand the difference between the apparent movement of the stars and the actual movement of the planets.

Pages 202 and 203 to the end of the first paragraph should be given careful treatment, since these pages develop an important science skill: the interpretation of tables. Have the children read these pages and consult the table on page 203. The pupils should not memorize the data or the table. The table should be used merely to give ideas of relative size, distance, speed, etc.

The rest of page 203 and page 204 should then be read and discussed. Give the children an opportunity to tell what they have read or heard about rocket ships or people from other planets. Ask them to tell which of these things might be true and which are not true. Such a discussion will give an opportunity to stress the importance of scientific thinking and give practice in testing ideas with facts.

To summarize the study of planets, have the pupils make nine small charts and place a drawing of one planet on each chart. Label each chart with the name of the planet. The pupils should collect information about the various planets and assemble it on the charts. The class may work together and make a set of charts or each pupil may make a separate set.

Have the children watch for articles on Mars and the other planets in newspapers and magazines. There is currently much interest in the possibility of some form of plant life on Mars, and reports of observations and theories often appear in the papers. For additional activities, see *Things to Do*, page 213, Nos. 2, 3, and 4.

Questions (Page 204)

1. The earth, because that is the planet on which we live.
2. Mercury, Venus, Mars, Jupiter, Saturn, Uranus (barely).
3. Neptune, Pluto.
4. Answers will vary. Refer to the table on page 203 as well as to the text.
5. Venus and Mars. Mars has air and water. Venus might have, although we cannot see through its clouds to find out.
6. *Alike:* Both are very bright, are sometimes called "morning star" or "evening star," and both have thick clouds around them. *Different:* Jupiter is much larger, much farther from the sun, and has eleven moons while Venus has none.
7. Planets near the sun move faster. Those far away have longer years.

What are comets? (Pages 205-206)

Concepts

1. Comets are made up of gases and little bits of solids.
2. The orbit of a comet and the orbits of the planets often cross.
3. The time of appearance of comets can be predicted.

Procedure

Probably none of the children will have seen comets, but some may have heard of them. To start the problem, ask the pupils to tell what they know about comets. Then have them read pages 205 and 206 and study the pictures to see what a comet looks like and how it travels. The problem may be concluded by letting the pupils discuss the question, "Why do you suppose people are no longer afraid when a comet appears?" Bring out the value of the work of astronomers, the people who study the stars and other objects in the sky. Pupils should realize that years of time and energy have been spent to determine the facts of science and that people are no longer afraid of these happenings when they learn that the causes are natural.

Questions (Page 206)

1. *Different:* A planet is round and travels in an orbit that is nearly a circle, while a comet

has a head and usually a tail and travels in a long, oval orbit. *Alike:* Both reflect the sun's light; both travel around the sun regularly, and so scientists can predict when they will be visible.

2. It must be near both the earth and sun.
3. Yes. They travel around our sun.
4. Away from the sun.
5. Yes. He observed very carefully, figured out what had happened, and then made a prediction that helped prove his thinking correct.

What causes an eclipse? (Pages 207-210)

Concepts

1. An eclipse of the sun is caused by the moon passing between the earth and the sun.
2. An eclipse of the moon is caused by the earth passing between the moon and the sun.

Experiments

PAGE 207: To show how the moon can cause an eclipse of the sun.

MATERIALS: Penny, half dollar.

PAGE 208: To show why there is not an eclipse every time the moon passes between the sun and the earth.

MATERIALS: Penny, half dollar.

Information for the teacher

PICTURES. PAGE 208. *Bottom left,* total eclipse of the sun. The mist of silvery white light around the sun during an eclipse is called the *corona.* During a total eclipse the prominences can be seen. These are great jets of hot gases coming from the surface of the sun. With an instrument that has been recently developed, the prominences can be photographed without waiting for a total eclipse. These photographs help scientists determine what gases make up the sun. *Bottom right,* partial eclipse of the sun.

PAGE 209. *Bottom,* eclipse of the moon.

TEXT. An almanac such as the *World Almanac* tells when eclipses will occur and where they will be visible. Possibly an eclipse may occur where it can be seen by the class. Newspapers usually carry articles about eclipses just before they occur.

Procedure

Have the pupils recall the story of Columbus and the eclipse of the moon. Be sure that the children understand the meaning of the word *eclipse.* Ask them whether there may be other eclipses than those of the moon. Bring out the fact that there are eclipses of the sun also. The children may have had experiences with eclipses. Let them tell about their experiences or what they learned from talking with people who have seen an eclipse. Then ask the pupils to give their ideas of what causes an eclipse. Write a list of these ideas on the board.

Now have the children read pages 207-210, do the experiments on pages 207 and 208, and study the pictures to find out how eclipses are caused. Ask such questions as "What hides the sun (or moon)?" "Can the eclipse be seen from all parts of the earth?"

To make sure that the children understand the two kinds of eclipses, have them make diagrams on the board to show the relative positions of the sun, moon, and earth at the time of an eclipse of the sun and at the time of an eclipse of the moon. Then let the pupils compare what they have learned about eclipses with the ideas written on the board at the beginning of the problem. For additional activities, see *Things to Do,* page 213, Nos. 1 and 6.

Questions (Page 210)

1. The moon comes directly between the earth and the sun.
2. The moon is nearer; so it looks larger.
3. A great, silvery white mist around it.
4. The shadow of the earth. That the earth is round.

What is beyond the solar system? (Pages 210-212)

Concepts

1. Distances between the stars are so vast that scientists measure them in light-years.

2. A light-year is the distance that light travels in one year.

3. All stars are millions of miles apart.

4. There are billions of stars in the universe.

Procedure

This problem is aimed primarily at giving the pupils an idea of the vastness of the universe. Have them begin by looking at the star maps on pages 210 and 211. They should notice that certain stars are labeled with different numbers of light-years. (Pupils may recall these stars from the study of the constellations in *Discovering Our World, Book One*, Unit 5.) Then let the children read text down to the first paragraph on page 212 to learn the meaning of *light-year*. Have them figure out how much farther away from the earth Betelgeuse and Rigel are than Sirius is. This will help them understand that Betelgeuse and Rigel must be large and bright stars to be seen as clearly as Sirius when they are so much farther away.

Now have the children read the rest of the problem and discuss the ideas of space presented there. To summarize the problem, have the class make a list of the facts that seem most startling to them. The list will impress on them the fact that the universe is extremely vast. See also *Things to Do*, page 213, No. 5.

Questions (Page 212)

1. The distance light travels in one year, or nearly six trillion miles. All other units of measurement are too small; it would take too many units to measure such great distances.

2. Thirty trillion miles, or about 5 light-years.

3. 500 years.

4. The billions of stars in the universe.

Questions to answer (Page 213)

1. Should include sun, earth and other planets, their moons, comets, stars, and galaxies.

2. Earth, Sun, a comet, Pluto, Saturn, Moon.

3. Other planets travel in their own orbits in the same direction around the sun. A comet's tail is so thin it can cause no harm.

4. The things in the universe are so very far away that even our best telescopes cannot show scientists all that they want to know.

5. (*a*), (*c*), (*d*), (*f*), (*g*).

6. Moon, Venus, Sun, Sirius, Arcturus, Betelgeuse, Rigel.

7. The third column of the table on page 203. (The distances in inches will be the same as the figures in the column.) Probably not, because Pluto would be 3675 inches away or 306¼ feet (slightly longer than a regulation football field).

Things to do (Page 213)

1. Most almanacs give eclipses for the year.

2. See table on page 203. Since Mars' speed is slower than the earth's and it is farther from the sun, the earth will make 1.88 trips around the sun while Mars makes one. When the earth passes Mars (they will both be on the same side of the sun), they are closest. When they are on opposite sides of the sun, they will be farthest apart.

3. The planetarium is an optical instrument by which images of the sun, moon, planets, and stars are projected on a large dome. There are planetariums in Chicago, Los Angeles, Philadelphia, New York, Pittsburgh, Springfield (Mass.).

4. See *Nature Magazine* or *Junior Natural History*. Refer to the pictures on pages 200 and 201. Drawings will show differences in the way in which planets and stars move across the sky.

5. See almanacs and encyclopedias. Some large telescopes are at: Yerkes Observatory, Williams Bay, Wisconsin; Lick Observatory, Mount Hamilton, California; University of Pittsburgh; U.S. Naval Observatory, Washington, D.C.; University of Virginia; Ohio Wesleyan University, Delaware, Ohio; Mt. Wilson, California; Lowell Observatory, Flagstaff, Arizona; Mt. Locke, Fort Davis, Texas; Mt. Palomar, California.

6. See an almanac. Look through a piece of smoked glass or an exposed film to watch the sun.

UNIT 8. *How Do Airplanes Fly?*

Purpose and scope

In recent years, America has become air conscious. This is particularly true of the younger generation. Boys and girls want to know how an airplane is built, how it can stay up in the air, and how it can be controlled. Although some children in the class may have been up in planes, many others probably have not. They want to know what an airplane trip is like. This unit answers these questions and many others. As new concepts are developed, many concepts taught earlier in the series are re-used and extended.

Science background

Look and Learn: Unit 2, Machines; Unit 3, Days and Days

All Around Us: Unit 2, Getting Work Done; Unit 3, Sun, Wind, and Weather

How Do We Know?: Unit 4, Wheels and Levers

Discovering Our World, Book One: Unit 2, Why Do All Living Things Need Air and Water? Unit 6, What Can Magnets Do?

Discovering Our World, Book Two: Unit 2, What Makes Things Move? Unit 3, How Is Our Work Made Easier? Unit 4, How Do Heating and Cooling Change Materials?

Discovering Our World, Book Three: Unit 2, Why Does the Weather Change? Unit 5, How Do We Use Electric Current?

General concepts

1. An airplane always weighs more than air.
2. There are different kinds of planes.
3. To get an airplane into the air and keep it there, the upward force must be equal to or greater than the downward pull of gravity.
4. Airplanes are built so that the force of the air upward on the wings is greater than the downward force of air above the wings when the plane is in motion.
5. A propeller drives a plane forward by pushing back on the air.
6. Instruments tell the pilot the air speed, height, direction, etc., of the plane.
7. The direction of an airplane is controlled by certain parts that the pilot can move.
8. The energy to drive planes is supplied by gasoline engines or jet propulsion.
9. Airplanes carry millions of people and tons of freight every year.
10. Air lines use various ways to make flying safer.

Introducing the unit (Pages 215-216)

Information for the teacher

PICTURE. PAGE 214. A four-engine Boeing Stratocruiser flying over Manhattan Island, New York.

TEXT. Much valuable help in the teaching of a unit on airplanes is made available to teachers by the large air lines. United Air Lines has a school and college service that will furnish material of suitable grade level to teachers upon request. Their *Aviation Handbook for Intermediate Grades* contains much important information. Write to United Air Lines, Inc., Department of School and College Service, 231 South LaSalle Street, Chicago 4, Illinois. American Airlines sponsor Air Education Research, which publishes *Air Education News*, a very useful publication distributed without charge to teachers on request to Air Education Research, 80 East 42nd Street, New York 17, N.Y. Information about other visual aids can be had from both of these air lines.

A very helpful book just released to the public by the government is *Introduction to Airplanes*. (Catalogue No. N17.25: A 17-7-944.) When ordering, give the title and the catalogue number. This is a 232-page illustrated book, written in clear, understandable language so that it is usable by those whose hobby is aviation and airplanes. Theories of flight as well as kinds of planes, instruments, etc., are treated. The book may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D.C., for forty cents. A list of publications of the Civil Aeronautics Administration of the Department of Commerce can also be obtained from the above office. See also the Bibliography.

Procedure

Pupils already have a great deal of information about airplanes. Many of them have built model planes or working models that can fly. Still others have taken trips in planes. They are familiar with speed records and distance records. To introduce the unit, many kinds of questions can be raised and discussed before the pupils are referred to the book. For example, do you think that airplanes will ever replace passenger trains? Why or why not? What are the advantages of air travel over land travel? What are the disadvantages? What uses can be made of planes that are not possible with other kinds of transportation? How many times faster has a plane traveled than an automobile? A locomotive? A ship? In what ways is an airplane different from a balloon? From a dirigible? What new kinds of planes are being used? How is steering a plane different from steering an automobile?

The introductory section is focused mainly on a discussion of the uses of airplanes. Before referring the pupils to the text, have them list as many uses of airplanes as they can. Write these on the board. Have them read pages 215-216 to find additional uses. Leave the list on the board and ask the pupils to try to find still other uses.

What are the different kinds of airplanes? (Pages 216-218)

Concepts

1. An airplane always weighs more than air.
2. Most airplanes have an engine that turns a propeller, wings, fuselage, and landing gear.
3. There are different kinds of planes.
   a) Seaplanes are airplanes that take off and come down on water.
   b) Amphibian planes can take off and come down on either land or water.
   c) A glider has no engine or propeller; some way must be provided to get it into the air.
   d) A helicopter has no wings but has rotating blades on top of the fuselage; it can go straight up or come straight down and fly backward, forward, or sideways; it can even stand still in the air.

Procedure

The children should learn the names of the different parts of a plane, since these are constantly used in descriptions of planes and their operation. To introduce the problem, let the pupils read the text and examine the pictures on pages 216, 217, 218, and 219. Then have the children bring pictures of various kinds of planes to class, as suggested in *Things to Do*, page 239, No. 1. They should mount the pictures on cardboard. Hold up each picture and have the children decide whether the plane is a monoplane or a biplane, glider or helicopter, a land plane, amphibian plane, or a sea plane. Pictures of different kinds of planes can also be placed on the bulletin board. Have the children identify and label the different parts of the plane, as shown in the picture on page 216. Some planes shown in flight have no landing gear visible because they are built with wheels that can be pulled up after the plane leaves the ground. These are, of course, either land planes or amphibians.

Questions (Page 218)

1. So they can take off or land on ground, water, or snow and ice.
2. Fuselage. Nose. Tail.
3. Having one pair of wings. Having two pairs of wings. Monoplane.
4. It has no wings, no propeller on the nose but a set of rotating blades above the fuselage and a small propeller on the tail. Not only can

it fly forward, but it flies backward, sideways, straight up and down, or even stands still in the air.

How is an airplane kept up in the air? (Pages 219-224)

Concepts

1. The Wright brothers' airplane was the first successful plane because they had invented a better set of controls.
2. To get an airplane into the air and keep it there, the upward force must be equal to or greater than the downward pull of gravity.
3. Airplanes are built so that the force of air upward on the wings is greater than the downward force of air above the wings when the plane is in motion.
    - *a*) Air pushes in all directions—downward, upward, and sideways.
    - *b*) The force of air moving against the slanting wings of the plane helps overcome the force of gravity.
    - *c*) The force of the air down on the wings is less than the force of the air up on the wings; this helps overcome the force of gravity.
    - *d*) The force of air is less when air is moving fast.
    - *e*) The wing is curved so that the air moves faster over the top of the wing than over the bottom of the wing.
4. The upward force of air on the wings is called the *lift*.
5. The propeller drives the plane forward by pushing back on the air.

Experiments

Pages 220-221: To show that air pushes upward as well as downward.

Materials: Glass tube, glass of water, piece of smooth cardboard.

Page 222: To show that when air moves faster over the top of a surface than under it, the force of the air is greater up than down.

Materials: Two strips of paper one inch wide and ten inches long.

Pages 223-224: To show that air can lift something when it pushes up.

Materials: Glass U-tube, water.

Procedure

The concepts should be developed in the order given in the list above. A proper understanding of these concepts is essential to the solution of the problem. To begin the unit, have the children read and discuss the text down to the end of the second whole paragraph of the first column on page 220.

Before the pupils read the explanation that starts at the bottom of the first column on page 220, ask some questions about gravity such as: "What happens if you let go of a stone you are holding in your hand?" "Why?" "If you throw a ball in the air, what will happen?" "Why?" "What do you have to do to throw the ball higher in the air?" "Why does the ball not keep right on going up?" "What makes it come back to the earth?" "If you lift a bucket of water off the ground, what do you have to do?" "Why do you have to use force to lift the bucket?" "Why do you think that an airplane must have an engine?" "What happens if the engine stops running?" "How do you think an airplane is able to stay in the air?" (You will, of course, not get a complete answer at this point. It is desirable to have the pupils anticipate the explanation. The questions you have raised will lead them to see what the problem is.)

Now raise the question, "Do you think that an airplane could fly if there were no air?" Boys will probably answer, "It could not fly; air is necessary." Then say, "Before we can find out how the air helps an airplane fly, we will need some facts about air." Next have pupils read from the bottom of column one to the experiment in the last paragraph on page 220. Ask, "What facts about air are given?" List these on the board. Then have the children read and do the experiment and answer the questions. Ask "What does the experiment show?" Write on the board the fact "Air pushes upward as well as downward." Then do the experiment with the glass and cardboard. Emphasize that the bottom of the glass cuts off the force of the air so that it does not press down on the water inside the glass.

To show how the moving air lifts a kite, you can make a small kite and hold it in front of an electric fan. If the face of the kite is held straight up and down, the air will simply move it backward. If the face of the kite is held at a slant, the kite will move upward.

In doing the experiment in which you blow over the top of the strip of paper held to the lips, be sure that the children see the forces that are acting. Make a drawing on the board like the one shown in the picture. Ask, "What pulls the paper down?" Then draw an arrow down from the lower part of the paper and label it "Gravity is pulling down." Ask, "Is air pushing up on the paper? Is air pushing down on the paper?" Draw arrows showing air pushing up and also air pushing down. Then let the pupils do the experiment. Get the children to see that the force of gravity is still the same but that the force of the air pushing up must be greater than the force of the air pushing down. Then ask, "Did the air move faster over the bottom of the paper or over the top of the paper?" "When air moves faster, does it push harder or not as hard on the paper?" "How do you know?" List the facts on the board.

The next experiment with the two strips of paper verifies the conclusion that the air has less force down on the top of the paper than it does up on the paper, because the air is moving faster. Children will naturally believe that blowing between the two strips will force the strips farther apart. Before they do the experiment, ask them, "What do you think will happen?" "If the papers move farther apart, what will this show?"

Now refer them to the picture of the wing on page 222. Raise questions such as, "What is the shape of the wing?" "Does the air traveling over the wing go faster, slower, or at the same speed as the air under the wing?" "What effect will this have on the force of the air down on the wing?" "Will there be more force up on the wing or down on the wing?" "Why does the plane stay in the air?" List the facts on the board. Pupils can now understand why an airplane must be moving to stay in the air. There will be no upward force on the wings unless the air is rushing over and under the wings. Let the pupils read the first three paragraphs and the summary on page 223 to check their conclusions.

The children are now ready to do the experiment with the U-tube described on page 223 and pictured on page 224. This shows that air can lift something when it pushes up. Now let the pupils read and discuss the rest of the problem. For additional activities, see *Things to Do*, page 239, Nos. 4, 5, 7, 9, 11, and 14.

Questions (Page 224)

1. Answers will vary.

2. The plane was light; the gasoline engine gave enough power without too much weight; and most important of all, the controls were better.

3. The wing is slanted so that the air rushes against the underside of the wing when the plane is moving and pushes upward. The wing is shaped so that air must move faster over the curved top than the underside; this makes the force less on top. By increasing force underneath and decreasing force on top, the lift becomes greater than the weight of the plane. See the picture on page 222.

4. It pushes back on the air, driving the plane forward fast enough to keep it up in the air.

5. Air rushing against the slanting underside of the wings; air rushing over the curved top of the wings. Second way.

How is an airplane controlled? (Pages 225-228)

Concepts

1. Instruments tell the pilot the height, the air speed, the direction, etc., of the plane.

2. The direction of an airplane is controlled by certain parts that the pilot can move.

a) Moving the rudder turns the plane to the right or left.

b) Moving the elevator makes the nose of the plane point up or down.

c) Moving the ailerons makes the plane tilt sideways to the left or right.

3. The speed of an airplane engine is controlled by the throttle.

Observation

PAGES 226-227: To observe the parts that control an airplane.

MATERIAL: Small model airplane or toy glider.

Procedure

To start the problem, have the pupils read and discuss page 225. They should also examine the picture on that page. Probably the best way for the pupils to learn how the controls of an airplane work is to have the pupils make a table on the board which shows how the plane moves when the rudder, elevator, and ailerons are moved. A model airplane can be made from cardboard. Cut out the movable parts and fasten them with scotch tape so that they can be moved.

Now have pupils read the paragraph on page 226 dealing with the rudder. They should also examine the pictures at the top of the page and move the rudder on the plane. Show them what happens to the nose of the plane when the rudder is moved to the right or left. Then have pupils tell what to write on the board. Be sure that the children understand why the airplane will move in a certain direction. Guiding a plane is merely a matter of arranging the controls so that the wind will strike the surfaces in a certain way. Carry on the same procedure with the elevator and ailerons.

To show what happens when the plane leaves the ground for a short flight and then returns, have some pupil demonstrate with the cardboard plane. In other words, at the take-off the elevator is lowered (have pupil lower the elevator), the tail is lifted off the ground (have pupil do this), and so on for the flight described on pages 227-228. The pupils should then read and discuss the rest of the problem. For additional activities, see *Things to Do*, page 239, Nos. 2 and 3.

Questions (Page 228)

1. It can go up and down or tilt sideways as well as go forward and to the right or left.

2. List may include: Taxi to the end of the runway; push rudder to turn into the wind; open the throttle; push stick forward to lift the tail; watch air speed; slowly pull stick back to take off. For a landing: circle field to line up a runway into the wind; push forward on stick to point nose down while gliding toward end of runway; when near the ground, pull back on stick to lower tail; close throttle.

3. Wind rushing past wings gives extra lift.

4. The two landing wheels and the tail touch ground at the same time.

5. *Tachometer* shows how fast the engine is turning. *Altimeter* shows how high above the earth the plane is flying. *Rudder* is used to make the plane turn right or left. *Stick* controls elevator and ailerons. *Elevator* raises or lowers tail to make nose point up or down. *Fin* helps keep plane flying straight. *Compass* shows direction of flight. *Air-speed indicator* shows how fast plane is traveling through the air. *Stabilizer* helps keep the plane flying level. *Ailerons* are used to raise or lower each wing to make the plane tilt sideways. *Throttle* controls flow of gasoline into engine.

What kinds of engines drive airplanes? (Pages 229-231)

Concepts

1. There are two kinds of gasoline engines used in airplanes today.

a) The in-line engine has its cylinders in a straight line with the propeller shaft.

b) The radial engine has its cylinders arranged around the propeller shaft like the spokes of a wheel.

2. A pump called a supercharger is used to get more oxygen into the cylinders of an engine

when the plane is high above the earth where the air is thin.

3. Jet propulsion drives a plane forward by the backward rush of expanding air.

Experiment

PAGE 231: To show how a backward rush of gas can drive something forward.

MATERIAL: Toy balloon.

Procedure

Have the pupils recall some of their experiences with the gasoline engine of an automobile. *Discovering Our World, Book Two*, page 62, has a picture of the engine in an automobile. Show the children this picture and point out that the up-and-down motions of the pistons (the parts that move up and down inside the cylinders) make the shaft connected to them move round and round. This same process takes place when an in-line or radial engine turns a propeller. Review the facts that the liquid gasoline is mixed with air and changes to a gas, that the mixture of gas and air goes into the cylinder of the engine, that a spark explodes the mixture, and that the force of the explosion moves the piston in the cylinder.

Now have the children read down to the last paragraph on page 230 and examine the pictures on that page. After discussing the text, they should do the experiment on page 231 and read to the end of the problem. *Things to Do*, page 239, No. 10, suggests an additional activity.

Questions (Page 231)

1. It had to be both powerful and not too heavy.

2. *Different:* An in-line engine has cylinders placed in a straight line with the shaft and cooled by a liquid. A radial engine has cylinders placed in a circle around the shaft and cooled by air rushing past. *Alike:* Both use gasoline and may have more than one row of cylinders.

3. Superchargers press thin air together and force it into an engine. When a plane flies high above the earth where air is thin, it needs extra oxygen to burn the gasoline completely.

4. No. Jet-propelled planes are driven by the backward rush of hot, expanding gases.

What is an airplane trip like? (Pages 232-238)

Concepts

1. Airplanes carry millions of people and tons of freight every year.

2. Air lines use various ways to make flying safer.

  a) Controllers or dispatchers in the control tower of the airport give the signal when the runways are all clear for taking off and landing.

  b) De-icers remove the ice from the wings and other parts of the plane.

  c) Beacons tell the pilot where he is and mark obstructions.

  d) The radio beam guides the pilot when clouds or fog hide beacons or other lights.

Procedure

This problem gives the children an idea of what happens on an airplane trip. If some child has taken a trip in a plane, ask him to tell his experiences. After discussion, the children should read the story to find out what an airplane trip is like. The whole story should be read before any questions are asked, because the aim is a bird's-eye view of an airplane trip. The questions at the end of the problem provide a guide for the discussion. Children can also be asked to tell how an airplane trip is different from a train trip. This will help bring out the precautions that are necessary for safe travel by plane. For additional activities, see *Things to Do*, page 239, Nos. 6, 8, 12, and 13.

Questions (Page 238)

1. List may include: handling of passengers (checking tickets, weighing luggage, checking safety belts, etc.); loading the plane (baggage, mail, and food); preparing the plane (a check by mechanics, fueling); and pilot duties (reading all weather reports, filing flight plan, checking wind, contacting control tower, etc.).

2. Because bad weather is a great danger to flying; direction and speed of wind may determine at what height plane is to be flown; weather often changes very suddenly.

3. *Safety:* mechanics keep planes in good working order; pilots must have good health and a great deal of training and experience; latest weather reports are given to the pilot; the controller prevents accidents at the airport; constant radio contact is kept with ground stations; planes are equipped with automatic pilots, de-icers, lights, etc.; and on the ground, there are such aids as wind tees, beacons, radio signals, etc.

Comfort: comfortable seats with safety belts; hostess to serve food and care for passengers; water for drinking and washing is supplied; superchargers pump warm air into the cabin during flight in cold air; air-conditioning units make air comfortable when plane is on the ground.

4. Answers will vary, but may be similar to the following: *Wind-direction indicator* shows the direction of the wind over the ground; may be a wind sock or wind tee. *Dispatcher or controller* helps prevent accidents by directing airport traffic; instructs pilots by radio. *Drag* is the backward push of air on a plane in flight. *Light beacon*, one revolving light and two fixed lights mounted on a tower, marks an airway by flashing light signals to pilots; may also mark mountains or other obstructions. *Radio beam* is a steady hum a pilot hears when flying on course. *Wing flaps* can be lowered to give a plane extra lift when taking off or to slow it down when landing. *Control tower* is the glassed-in tower at an airport from which the controller can see all runways. *Head wind* is a wind blowing from the direction in which a plane is heading. *Tail wind* is a wind blowing in the same direction a plane is flying. *De-icer* is a rubber instrument on the front edge of a wing or tail into which air can be pumped to make it bulge and break up ice. *Running lights* on a plane are red, green, and white lights which are turned on at night to prevent accidents in the dark.

Questions to answer (Page 238)

1. Airplanes are faster, carry more weight, can be steered, etc.

2. See drawing, page 216. Tail keeps plane straight and level and helps steer it. Wings lift the plane up in the air and help steer it. Engine supplies power to push it forward. Pilot's cockpit contains seats for pilot and co-pilot, instruments, and radio equipment. Fuselage holds the passengers and cargo. Landing gear supports plane when on the ground. Propeller moves the plane and helps it stay up in the air.

3. Bad weather. Clouds, fog, rain prevent pilot from seeing the ground. This is especially dangerous on landings and take-offs. Icing may harm the propeller and shape of wings, forcing the plane down. High winds and storms may damage plane or throw it off course.

4. Running increases the force of the air against the kite. The kite is tilted so that air pushes harder on the underside than on top and thus lifts it up.

5. *Like:* Both have body, wings, and tail. *Different:* Bird gets energy from muscles and lift by moving wings. Airplane has an engine and depends for lift on the force of air on specially shaped wings.

6. They do not need long runways or large airports but can land or take off from a very small space. The fact that they can move in any direction or stand still in the air makes them more useful for rescue work, observation, reaching out-of-the-way places, etc.

7. *Advantages:* It is many times faster and can be used to reach places where trains and boats cannot go. *Disadvantages:* Not all towns and cities have airports. Because of weather, planes cannot fly at all times.

8. The lighter the plane, the less force needed to lift it. Materials must be strong to resist the force of air against them.

Things to do (Page 239)

1. Pictures may be found in any of the many aviation magazines, *Popular Mechanics*, *Popu-*

lar Science, Science Illustrated, Current Science and Aviation, Life, etc.

2. Some students may have powered models built at home. If not, even small cardboard models will help the class learn the parts of a plane. Small models can be used in making a model airport in activity No. 8.

3. Individual report.

4-5. Individual or group activity.

6. One source is the Civil Aeronautics Administration, Dept. of Commerce, Washington 25, D.C.

7. This poem may be found in anthologies such as *The Home Book of Verse for Young Folks* by B. E. Stevenson. New York: Henry Holt & Co., 1929.

8. Individual or group activity.

9. See encyclopedias under "Balloon." Joseph and Jacques Montgolfier are credited with beginning aerial navigation when, in 1783, they sent a smoke-filled paper balloon 1000 feet over Paris.

10. See almanacs. Newspaper offices and airports may have more recent information.

11. Langley, secretary of the Smithsonian Institution, first demonstrated the laws of flight with successful models, though his two tests with full-sized planes failed. In 1896, the year of Langley's first test, Chanute made his first successful glider flight. Only a few days after Langley's second test in 1903, the Wright brothers flew their plane at Kitty Hawk.

12-13. Individual reports.

14. All of these came to a disastrous end. The first three were built by the United States. The Shenandoah was torn in two by a violent shift of wind in Ohio in 1925. The Akron was destroyed by a storm off the New Jersey coast in 1933. The Macon fell into the ocean off the California coast in 1935. The Hindenburg, a German-built ship, made ten round trips across the Atlantic in 1936. But the next year it caught fire as it came to its mooring in Lakehurst, New Jersey, and burned in half a minute.

UNIT 9. *Where Do New Plants and Animals Come From?*

Purpose and scope

In this elementary treatment of reproduction, certain broad understandings should be emphasized. The pupils should complete the unit with these understandings clearly in mind: (1) Every living thing comes from another living thing of the same kind. (2) Every living thing begins its life as a single cell, which grows and divides into more cells. Throughout the unit, these ideas are continually stressed. Each method of reproduction illustrates them. In this way, pupils should come to see that the same general principles underlie all reproduction. Only the methods are different.

As indicated in *Science Background,* this unit extends many concepts developed in earlier units. These concepts should be recalled, or retaught if necessary, as the study of the unit progresses.

Science background

Look and Learn: Unit 1, Animals; Unit 4, Outdoors

All Around Us: Unit 1, Animals; Unit 4, Plants

How Do We Know?: Unit 1, Animals; Unit 3, Plants

Discovering Our World, Book One: Unit 1, How Are the Things of the World Put in Groups? Unit 2, Why Do All Living Things Need Air and Water? Unit 8, How Do Animals and Plants Grow?

Discovering Our World, Book Two: Unit 1, How Do Living Things Help and Harm Each Other? Unit 8, Where Does All the Food of the World Come From? Unit 9, How Can You Make a Garden?

Discovering Our World, Book Three: Unit 4, How Do Germs Make You Sick?

General concepts

1. Plants with flowers can make seeds from which new plants will grow.
2. A flower has different parts that help in making seeds.
3. A flower can make seeds only after a pollen cell joins with an egg cell.
4. A seed has three parts: the tiny new plant, the food stored around it, and the seed coat that protects the new plant and its food.
5. The part of any plant that contains the seeds is called the fruit.
6. Some plants (annuals) live only one year; others (biennials) live two years; still others (perennials) live more than two years.
7. Some plants can make new plants from parts such as stems, roots, leaves, and bulbs.
8. Plants without flowers cannot make seeds; they make new plants by dividing, budding, or producing spores.
9. Animals, like plants, come from another living thing of the same kind.
10. Every living thing begins its life as one little cell.
11. Some kinds of animals feed and protect their young; others do not.
12. The earth is not overrun with living things because many plants and animals die before they can produce others like themselves.
13. Even the living things that get a chance to grow do not live forever.
14. We should help conserve wild animals and plants because we need and enjoy them.
15. There are various ways of conserving wild animals and plants.

Introducing the unit (Page 241)

Procedure

One way to introduce this unit is to let the pupils examine the pictures. Many of the things illustrated could not have been seen without a magnifying glass or a microscope. A discussion of the question in the second paragraph on page 241 will bring out the progress of science that resulted from experiments and better instruments. From Unit 4, pupils should recall the importance of the microscope in the discovery and study of germs.

Another way to begin the unit is to ask the pupils the question stated in the unit title. From earlier experiences, they already know that some plants grow from seeds, others grow from spores; they also know that some animals hatch from eggs and others are born alive. Then have the pupils read and discuss page 241, which gives some examples of the non-scientific practice of drawing conclusions without enough evidence. Also urge the pupils to carry out the activity suggested in the last paragraph. It will raise some questions to be answered in the problems that follow.

What are the parts of a flower? (Pages 242-244)

Concepts

1. Plants with flowers can make seeds from which new plants will grow.
2. A flower has different parts that help in making seeds.
   a) Sepals protect the petals, pistil, and stamens until the flower opens.
   b) Pollen from the stamens must fall on the stigma of the pistil before a flower can make seeds.
   c) Many flowers will make better seeds if the pollen comes from another flower of the same kind.

Observations

PAGE 243: To observe the parts of flowers.

MATERIALS: Flowers showing petals, sepals, pistils, and stamens.

PAGE 243: To observe pollen.

MATERIALS: Microscope (optional), pollen.

Information for the teacher

PICTURES. PAGES 242-243. Most flowers vary from the ideal flower usually pictured diagrammatically. Some flowers do not have all the parts. Those that do, such as the flowers shown on these pages, may show variation in color, form, or number of parts. The lily is like the tulip, because the sepals are the same color as the petals. Only the petals are visible in the poppy. The sepals usually fall off when the flower opens.

The pistil of a flower usually consists of the swollen base, or *ovary*, where the *ovules* and later the seeds are formed; a long, slender stalk, called the *style;* and the sticky end of the style, called the *stigma*. In the tulip, the style is almost completely lacking. This gives the pistil more the appearance of a column than of a stalk.

Some flowers, such as the buttercup, have more than one distinct pistil. Very often the pistils are united at the base to make a compound pistil. Then there may be one style or several coming from the ovary. In the poppy, the stigmas of several pistils are united to form a ring.

A stamen consists of the long stalk, or *filament*, and the knoblike end of the filament, called the *anther*, in which the pollen is formed. The number of stamens varies. The apple, buttercup, and poppy have many stamens, while the tulip and lily have only six. Anthers also vary greatly in color and shape.

Procedure

The parts of a flower are taught here only to help pupils understand how a flower makes seeds. When the class meets, have on hand various kinds of flowers whose parts can easily be identified. If possible, have some of those illustrated on pages 242-243. To introduce the unit, have the pupils find the different parts of the flowers by using the pictures on page 242 as guides. Since the parts vary in different flowers, the pupils should examine as many different flowers as possible. (If no flowers are available, pupils may learn the parts from the pictures on page 242. Practice in recognizing the parts is given by the pictures on page 243.) The pupils should now read the text down to the end of the first column on page 243 to check their findings and acquire additional information. Urge them to carry out the activity in the last paragraph.

Pupils should next examine pollen under a microscope. If a microscope is not available, have them use the picture at the left on page 244. Now let the pupils read and discuss the rest of the problem. They may wish to tell about experiences in which they watched bees or other insects go from flower to flower, carrying pollen. For an additional activity, see *Things to Do*, page 269, No. 13.

Questions (Page 244)

1. Petal, sepal, stamen, pistil, stigma.
2. Protect the petals and other parts of the flower until it opens.
3. The stamens may bend over and touch the pistil. If the stamens are taller than the pistil, pollen may drop from the stamens and fall on the pistil.
4. Carried by the wind or insects.
5. New plants will grow from the seeds.

How do flowers make seeds? (Pages 245-249)

Concepts

1. A flower can make a seed only after a pollen cell joins with an egg cell.
   a) When the two cells join, the new cell is made.
   b) The new cell grows and divides into more new cells that make a tiny plant.
   c) Other cells make food that is stored around the young plant or make a covering for the plant and its food.
2. A seed has three parts: the tiny new plant, the food stored around it, and the seed coat that protects the new plant and its food.
3. The part of a plant that contains the seeds is called the fruit.
4. Some plants (annuals) live only one year; others (biennials) live two years; still others (perennials) live for more than two years.

Observation

PAGE 246: To observe some cells.

MATERIALS: Microscope, thin skin from an onion, algae.

Information for the teacher

Pictures. Page 245. *Left*, pollination. *Right*, fertilization. These pictures are, of course, diagrams. The diagrams show one ovule in each ovary. The number of ovules varies greatly among plants. The buttercup has one to an ovary, the snapdragon two hundred or more. Within the ovule is the so-called embryo sac ("tiny sack" in the text) that contains the egg cell. At this level, the pupils need only to understand that the egg cell is inside the ovule (labeled "sack" in the diagram).

In the fertilization diagram, just one pollen tube is shown growing down the style to the ovule. Many pollen grains land on the stigma, and a number germinate and grow down toward the ovule. When there is more than one ovule, the first tube down enters the nearest ovule. The others are turned aside in some way and grow toward the other ovules. When there is only one ovule, the other pollen tubes stop growing when one reaches the ovule.

Page 246. The threadlike water plants are, *top*, the green alga *Spirogyra* and, *bottom*, the green alga *Ulothrix*. The one-celled plants are the blue-green alga *Gleocapsa*. They are all distinguished by a thick gelatinous sheath around them. Visible in each cell are the green chloroplasts and the nucleus. These and other common green algae can be found in the quiet waters of ponds and streams.

Page 247. A good botany text or a book on plants (see Bibliography) will give further information about the different kinds of fruits. The hickory nut shows the kind of fruit that has two kinds of protective covering for its seed; the green outer shell turns black and comes off, leaving the hard shell with which we are more familiar.

Other fruits like the pea are string beans, lima beans, soybeans, and fruits of locust trees; like the apple are pears and quinces; like the tomato are grapes, currants, gooseberries, and blueberries; like the cucumber are squash, pumpkin, and gourds; like the plum are peach, cherry, apricot, and nectarine.

Page 248. Nasturtium is an annual.

Page 249. Carrot is a biennial.

Text. Page 245. The part of the pollen grain that joins with the egg is the sperm that has been carried down to the egg in the pollen tube. After fertilization, the cell resulting from the union of the sperm and the egg grows and becomes the embryo. The rest of the embryo sac and the ovule around it develop into the other parts of the seed, namely, the food and the seed coat.

Procedure

When the pupils begin the study of this problem, have on hand some flowers that show the pistils and stamens clearly. Cut a pistil lengthwise to show the inside. After the pupils look at the living material, have them read the first three paragraphs and examine the diagrams on page 245. Be sure that the pupils understand that most plants will not look just like the diagrams although the plants will have the same parts.

Now have the pupils recall what they have learned about cells in earlier units (*Discovering Our World, Book Two*, Unit 8, page 213, and *Book Three*, Unit 4, page 102). Then let them read the last paragraph on page 245 and make the observation suggested in the first paragraph on page 246, using the pictures at the top of that page. Point out the fact that there are many sizes and kinds of cells but that they all grow in the same way.

Pupils are now ready to read the next three paragraphs on page 246, which tell how the new cell grows into a seed. Have them examine a soaked bean seed and compare its parts with those that they find in the picture at the bottom of the page. If possible, the pupils should look at other large seeds of this type and find the parts. From *Discovering Our World, Book One*, Unit 8, pages 197-198, the children may recall the parts of seeds. They should read the summary at the top of page 247 before studying the rest of the problem.

The next three paragraphs and the pictures on page 247 deal with fruits in the scientific sense. This use of *fruit* may be surprising to the pupils. Let the pupils read the text and examine the pictures. Be sure that they understand that *fruit* means the part that contains the seeds. Urge the children to look for as many different fruits as they can find. These may be brought to class and arranged in an exhibit.

Have the pupils recall from earlier science study how seeds grow into new plants. They should then read the rest of the problem and examine the pictures. The questions in the legends will help the children apply what they have learned. Be sure that the differences between *annual*, *biennial*, and *perennial* are understood. For additional activities, see *Things to Do*, page 269, Nos. 3, 6, 7, and 8.

Questions (Page 249)

1. (*b*), (*a*), (*c*), (*e*), (*f*), (*g*), (*d*).

2. The tiny new plant grows, sending down roots and pushing stem and leaves above ground. The food stored around the new plant is used until leaves can make food. The seed coat protects the tiny plant and its food until the plant sprouts.

3. The part of any plant that contains the seeds. Apples, oranges, tomatoes, pumpkins, bean and pea pods, etc.

4. *Annuals:* petunias and poppies. *Biennials:* cabbages and carrots. *Perennials:* trees and tulips.

How are new plants made from parts of plants? (Pages 250-253)

Concept

Some plants can make new plants from parts such as stems, roots, leaves, or bulbs.

Observations and experiments

PAGE 250: To observe that some plants grow from cuttings.

MATERIALS: Ivy plant, sharp knife, sand, water.

PAGE 251: To observe that some plants grow from underground stems.

MATERIALS: White potato, jar of water.

PAGE 252: To observe that some plants grow from leaves.

MATERIALS: Begonia plant, coarse sand.

PAGES 252-253: To observe how plants grow from bulbs.

MATERIALS: Onion bulb, knife, flower bulbs, dish, pebbles.

Information for the teacher

The method of reproduction described in this problem is known as *vegetative reproduction*. It has great value because it enables us to grow a mature plant in much less time than would be required to grow the plant from seeds. Also with many garden flowers and fruits, we destroy the seeds when we use the flower or fruit. However, vegetative reproduction of weeds makes many of them difficult to get rid of. The place on the stem from which strawberries and other similar plants send out roots and stems is known as the *node*. The underground stem is a *rhizome*. A shoot from a parent plant producing buds and a new plant is called a *stolon*. A *tuber* is a small, fleshy, underground stem or shoot having tiny leafy scales with buds or "eyes," as in the white potato.

Procedure

Ask the children whether they have ever seen anyone planting something other than seeds to start some new plants. Farm children may have helped cut up "seed" potatoes for planting. Others may have planted tulip or other bulbs in the fall or watched onion sets being planted in the garden. Some will have seen their mothers take slips from geraniums or other house plants, and most will be familiar with growing narcissus bulbs in water. List the ways mentioned on the board.

After discussing these ways of growing plants, have the children set up as many of the experiments with vegetative reproduction described in these pages as possible. They should follow the directions in the book by reading and looking at the pictures. Committees should be chosen to make sure that the plants are kept moist. As the children watch the plants over a period of time, they should refer to the text for an explanation of what they observe.

When the experiments are started, have the children read the problem to find out about the types of vegetative reproduction and to become familiar with the names of the different types. For an additional activity, see *Things to Do*, page 269, No. 10.

Questions (Page 253)

1. *Stems:* ivy, geranium, grapevine, willow, poplar; *runners*, strawberry; *underground stems*, quack grass; *buds:* potato; *roots:* raspberry, barberry, rose, blackberry, phlox, oriental poppy· *leaves:* begonia; *bulbs:* onion, daffodil, hyacinth, lily, tulip.
2. They will grow from roots or underground stems if the leaves or stems are cut off.
3. *Geranium:* make a stem cutting and plant it in moist sand to cover the lower joint; then when roots and leaves have grown, transplant into soil. *Blackberry:* make a root cutting.
4. The eyes are buds that grow into new plants.
5. No. There are underground stems such as white potatoes, and buds such as onion bulbs that grow underground.

How do plants without flowers make new plants? (Pages 253-256)

Concept

Plants without flowers cannot make seeds; they make new plants by dividing, budding, or producing spores.

Experiments and observations

Page 254: To watch yeast plants grow.

Materials: Yeast cake, sugar, warm water, test tube, cork, microscope if possible.

Pages 254-255: To show that mold grows from spores.

Materials: Slice of bread, dusty cloth, two dishes, magnifying glass or microscope.

Page 256: To observe spores from mushrooms.

Materials: Mushrooms, sheet of paper.

Information for the teacher

Pictures. Page 254. *Top,* yeast plants, some budding. Within the yeast plant may be seen oil globules and the clear-looking spots called *vacuoles.* These vacuoles contain a watery substance in which many materials are dissolved.

Page 254. *Bottom,* mycelium and spore cases of the bread mold *Rhizopus.* The left-hand picture shows the rootlike parts, or *hyphae,* of the mycelium that grow down into the bread and get food materials from the bread. Several spore cases can be seen on their stalks. The center picture shows a much enlarged spore case containing spores. In the right-hand picture, the case has broken, allowing the spores to escape. A spore does not contain an embryo plant as a seed does. A spore is a single cell, or a small group of cells, that can grow into a new plant.

Page 255. Either black or white paper may be used in making spore prints. Since some spores are white or very light-colored, the prints often show up better on black paper.

Page 256. *Left,* fern frond showing spore cases on the back of one leaf. Each of these brown dots is made up of groups of spore cases. A group of spore cases like this is known as a *sorus. Right,* moss plant showing stalked spore case called a *capsule.* This moss is the hair-cap moss *Polytrichum.* Children may find this and other mosses that show spore cases.

Text. Page 256. The seaweeds referred to are the algae. This whole group reproduces by spores.

Procedure

To start this problem, ask the children to name all the kinds of plants they can think of that have no flowers or seeds. From *Discovering Our World, Book One,* Unit 1, pages 38-43, they should recall that mushrooms, seaweeds, mosses, and ferns reproduce by spores instead of by seeds. After they have named as many of these as they can, ask them to recall what they learned about the reproduction of bacteria in Unit 4 of this book, pages 102-103.

After the discussion, have the class set up the experiment with the yeast plants to demonstrate reproduction by budding. They should also carry out the other activities suggested in the text. As in the previous problem, have the children follow the directions by reading the text and looking at the pictures. If a microscope is available, it will add greatly to the study of this problem. However, a good magnifying glass and the pictures in the text will enable the children to grasp the basic ideas of the problem.

When the pupils have examined as many non-seed-bearing plants as possible, have them read through the problem for further explanation and information. Be sure that the pupils understand that the buds of yeast plants are in no way like the buds of seed-bearing plants. See also *Things to Do*, page 269, No. 9, for an additional activity.

Questions (Page 256)

1. One cell divides into two cells.
2. Little swellings called buds break off and grow into new plants.
3. *Like:* Both can grow into new plants. *Different:* Spores are very much smaller and do not have the parts that a seed has.
4. Answers may include ferns, mosses, seaweeds, molds, mushrooms.

Where do new animals come from? (Pages 256-259)

Concepts

1. Animals, like plants, come from another living thing of the same kind.
    a) Some animals hatch from eggs laid by the mother.
    b) Some animals grow inside the mother's body.
2. Every living thing begins its life as one little cell.

Information for the teacher

Pictures. Page 257. *Left.* The spider is the female of the common garden spider, also called the golden garden spider. The male is much smaller and less conspicuous. The egg sac, which is usually about the size of a hickory nut, is made in the autumn. It is fastened securely by many ropes of silk in the top of some weed or shrub. In this sac, the young spiders pass the winter. Specimens of these spiders can be raised by keeping an egg case in a closed bottle. *Right,* the nest and eggs of a blackbird.

Page 258. The early divisions of a frog's egg.

Page 259. The katydid, like the grasshopper, goes through an incomplete metamorphosis; that is, it has only three distinct stages to its life history: the egg, the wingless young stage, and the adult. (See *Discovering Our World, Book One*, pages 189-190.) The young katydid differs from the adult in the absence of wings. It grows into an adult by adding wings and getting larger but not by changing form completely, as some insects do by going through four stages (complete metamorphosis). Katydid eggs may be found on the edges of leaves and twigs of trees in the fall.

Text. The phrase "born alive" refers to animals that are produced in a comparatively advanced stage of development. They have been nourished within the mother through a placenta. When they are born, they are in an active condition. Animals that bear young in this way are known as *viviparous* animals in contrast to the animals that lay eggs, or *oviparous* animals. Eggs, of course, are alive; but the animals within them do not arrive at an active state until after a period of incubation.

Most snakes are hatched from eggs; but some, such as the common garter snake, are born alive. All mammals except two kinds give birth to living young. The two kinds that lay eggs are found in Australia. One is called the duckbill, or platypus; the other is called the spiny anteater, or echidna.

Procedure

To begin this problem, ask the pupils to name the six main groups of animals they have learned about (*Discovering Our World, Book One*, Unit 1). Write these on the board. Then ask the children in which of these groups the young are born alive and in which they hatch from eggs. Write the answers after the names of the groups.

Now suggest that the class study eggs of various kinds to see how animals grow from one cell, as directed in *Things to Do*, page 269, Nos. 1, 2, and 5. If possible, get a hen's egg that is partly incubated. The children can see how the tiny chicken is beginning to form. Break the eggshell carefully and empty the contents into a saucer. The embryo may be seen more clearly if it is carefully lifted away from the yolk and put on a glass slide or dish. Pupils can also watch the development of frogs' eggs and toads' eggs if they bring them to school in the spring. They may be found in the shallow water of streams and ponds. Frogs' eggs are found in masses of jellylike substance and toads' eggs in strings. See *Discovering Our World, Book One*, Unit 1, pages 192-194.

When collecting the eggs, use a dipper and lower the dipper into a pail of the pond water. Do not pour the eggs into the bucket. Let the bucket stand until the water is at the temperature of the room in which the aquarium is located before transferring the eggs to the aquarium. To keep the eggs, at least three gallons of water are needed for a mass of eggs the size of a hen's egg. If the eggs are fertile and developing, they will hang with the black half uppermost; the white will soon turn dark. The best way to demonstrate the early divisions of a frog's egg is to make a ball of modeling clay and cut the ball with a knife to show how first two, then four, then eight, and then sixteen cells are made. See the picture on page 258. Salamander eggs are also interesting because the embryos can be clearly seen for some time before they hatch. However, they are not so commonly found as frogs' and toads' eggs. A magnifying glass gives a good view of the first stages of cell division in any of these eggs.

As the children study the living material, have them read down to the last paragraph on page 259 and look at the pictures. They will probably recall the metamorphosis of the frog and certain insects from *Discovering Our World, Book One*, Unit 8, pages 189-194. The text and pictures in that book may be used to review or supplement the concepts developed in this problem. When the concepts in this problem are clearly understood, have the class read the last paragraph on page 259, which summarizes the essential understandings so far developed in the unit.

Questions (Page 259)

1. Inside both is a tiny cell that can divide and grow into a new living thing. Both contain food for the young plant or animal, and both have protective coverings.
2. Most mammals are born alive, while birds are hatched from eggs.
3. As one little cell.
4. Cells divide, making more cells, which divide again.
5. *Born alive:* deer, mouse, some snakes. *Hatch from eggs:* robin, frog, turtle, most snakes, cricket.

How do animals take care of their young? (Pages 260-262)

Concept

Some kinds of animals feed and protect their young; others do not.

Information for the teacher

PICTURES. PAGE 260. The opossum is the only American representative of the group of animals known as Marsupials because they carry their young in a marsupium, or pouch. Kangaroos are the most familiar example of these animals. Opossums usually keep their young, which are extremely small and undeveloped at birth, in the pouch for about two months. Later, the young ride around on the mother's back.

PAGE 261. The quail is also called a partridge or bobwhite in some localities. Quail chicks can run about almost immediately after hatching, but the mother must help them find food and give them warmth and protection for two or three months.

Page 262. *Left*, larvae of the *Anisota virginiensis* or Virginian Anisota, closely related to the orange-striped oak-worm moth. *Right*, stickleback in the nest. This stickleback is found in the Great Lakes region and in fresh water from New York to Kansas.

Text. Page 260. Other hibernating animals are snakes, turtles, woodchucks, and chipmunks; also frogs and toads, which bury themselves in the mud at the bottom of ponds.

Procedure

This problem provides an excellent opportunity for children to tell about their own experiences with young animals and their observations of how mother animals care for their young. Almost every child will have had some such experience and will be able to contribute to the discussion. As the discussion proceeds, make a list on the board of the animals mentioned and what the children observed about them. After the children have told their experiences, have them read pages 260-262 and look at the pictures for additional information. See also *Things to Do*, page 269, No. 4.

Questions (Page 262)

1. Mammals, birds.
2. Those that have only a few.
3. Many lay their eggs near food, that is, on plants or near other animals that the young can eat. Some place food in the nest for them.
4. Answers will vary.
5. Pupils may have observed the placing and camouflaging of nests for protection and the behavior of a bird when an enemy approaches the nest.

Why is the earth not overrun with plants and animals? (Pages 263-265)

Concepts

1. The earth is not overrun with living things because many new plants and animals die before they can produce others like themselves.
    - *a*) Many cannot get all the air, food, water, room, light, and warmth that they need to grow.
    - *b*) Many are killed by enemies.
2. Even the living things that get a chance to grow do not live forever.

Information for the teacher

Pictures. Page 263. Milkweed pod and seeds escaping.

Page 265. The big tree of Tule, near Oaxaca, Mexico. This ancient tree has a circumference of about thirty-five yards three feet above ground.

Procedure

To introduce this problem, ask the children whether they have ever opened a milkweed pod like the one in the picture on page 263. Or ask them whether they have ever blown the seeds from dandelions as the children in the picture on page 241 are doing. If it is dandelion season, ask the children to look for some dandelions that have gone to seed. Use these (or the pictures) to start a discussion of the great numbers of seeds produced by many plants. Ask the children what would happen if all the seeds such as those from one milkweed pod became full-grown plants. Tell them to remember that there are several pods on one plant. If the children collected frogs' or toads' eggs earlier in the unit, refer to the great numbers of eggs in one mass. Have them recall that these eggs were laid by just one frog or toad. Ask what would happen if all these eggs became full-grown frogs or toads. Pupils may also wish to carry out the activity suggested in the second paragraph on page 263. Similar questions should be asked about the young that hatch from the eggs laid by one spider.

Then ask the children how they think all these seeds and eggs are kept from becoming full-grown plants or animals. What the children have already learned about the air and water requirements of living things (*Discovering Our World, Book One*, Units 2 and 8), the interrelationships of living things (*Discovering Our World, Book Two*, Unit 1) and about the requirements for growing plants in a garden (*Discovering Our World, Book Two*, Unit 9) should enable them to think of many things that limit the growth of plants and animals. Make a list of the pupils' explanations on the board. After the children have given all their ideas, have them read pages 263-265 to check their reasons, to find additional ones, and to learn something about the life span of plants and animals. A carefully planned field trip to make the observations suggested in the third paragraph on page 264 will enrich this problem.

Questions (Page 265)

1. The egg would probably be destroyed. Before long, there would be no new frogs to grow and produce more frogs.
2. Many fall where they cannot grow; some are eaten; others cannot get enough air, food, water, room, light, or warmth to grow.
3. Although a great many are produced, many do not live; and so the number that become full-grown is small.
4. Answers should mention that eggs are destroyed, young are killed, seeds and spores often do not get a chance to grow, and the old die.
5. Frog. Elephant. Goose.
6. Trees.

Why should we help conserve living things? (Pages 266-268)

Concepts

1. We should help conserve wild animals and plants because we need and enjoy them.
2. There are various ways of conserving wild animals and plants.
   a) Passing laws against picking certain wild flowers helps protect them.
   b) Establishing bird sanctuaries and other wild-life refuges gives animals a chance to grow and produce others like themselves.

Information for the teacher

Much information on conservation is available to teachers. State Departments of Agriculture or of Conservation will furnish pamphlets that describe local conditions and methods. The United States Department of Agriculture and the United States Department of the Interior have many helpful bulletins and pamphlets. The bulletins issued in connection with 4-H Club work are particularly helpful in teaching conservation at this level. Other organizations such as the National Wildlife Federation and the National Audubon Society are also excellent sources of information. (See Bibliography for titles and methods of obtaining information from these sources.)

Procedure

Before beginning this problem, make sure that the children understand the meaning of the word *conservation*. From *Discovering Our World, Books One* and *Two*, they should recall the meaning of conservation and some aspects of it related to wild-life protection. Refer also to the problem on the conservation of soil in Unit 3 of this book. Many children may belong to a group in which conservation is part of the program. Draw on as many experiences as possible to start the discussion.

This problem on wild-life protection can be most effectively taught if the teacher presents some of the problems of conservation that are peculiar to the locality, for example, disappearance or great decrease in numbers of some plant or animal. The pupils should try to decide (1) why the animals or plants are disappearing and (2) what can be done to correct this condition. Then they should read the problem to check their ideas. As a summary of the concepts developed in this problem, have the class make a list of the things they can do to apply these concepts. The list might include preventing the destruction of certain plants and animals, feeding birds, etc. Such projects establish valuable attitudes and habits to be carried from the classroom into everyday behavior.

If possible, have the class visit a fish hatchery or a bird sanctuary, or see some other phase of conservation. Otherwise, individuals may report on such visits. A copy of the local game laws should be obtained and referred to. The plants that need protection should also be learned. For additional activities, see *Things to Do*, page 269, Nos. 11 and 12.

Questions (Page 268)

1. Because we need them and enjoy them.
2. Do not harm eggs, birds, or wild animals; do not pick wild flowers.
3. Answers will vary.
4. Some places will become too crowded so that many living things will die. Other places will no longer have the things needed for animals and plants to grow.

Questions to answer (Page 269)

1. No. Try the experiment and show that it does not work. Then find out where snakes do come from.
2. No. Bacteria make no seeds but simply divide. Yeasts have buds instead. Ferns, mosses, seaweeds, and mushrooms grow from spores.
3. It must join with a pollen cell.
4. *Pistil* has egg sacks in which the eggs grow into seeds. *Wind* carries pollen to other flowers. *Pollen* sends down a tube to the egg sack; then a pollen cell joins with the egg so it can grow. *Bees* carry pollen from flower to flower. *Stamen* is the part that makes pollen. *Stigma* holds pollen on the pistil.
5. The eggs are so small that they cannot be seen without a microscope.
6. If the blossoms are fully open and have been fertilized, there is a chance that fruit will develop. But in most cases a heavy frost or freeze will prevent fruit from growing by killing the flower before a seed can be formed.
7. Yes. Vegetables such as tomatoes, cucumbers, squash, etc., are really fruits in the scientific sense.
8. Raspberry, peach, watermelon, grape. Each contains the seeds of the plant. Radish and carrot are roots. Potato is an underground stem. Onion is a bulb.
9. From another living thing like itself.
10. All living things are made of different kinds and numbers of cells. Living things grow as these cells divide to make more cells.
11. They may die and not produce more like themselves.
12. Many living things depend on trees for food and protection. When trees are destroyed, these living things must go elsewhere or die.

Things to do (Page 269)

1. Group activity. For details, see page 113 of this *Guidebook*.
2. 21 days.
3. Consult high-school or college biology, botany, or zoology texts.
4. See Bibliography and encyclopedias.
5. Grasshopper eggs are oval and about 3/16 inch long. In the autumn, they are laid in groups of a dozen to 150 in an oval pod in the ground. They hatch when warm weather returns in the spring.
6. Sepals and petals may have fallen off. Perhaps some stamens are left. The pistil will be left but will be enlarged at the base into a seed pod or other type of fruit.
7. Burbank cross-pollinated plants that possessed characteristics which he wished to develop; then by careful selection he finally produced plants of superior quality. He is best known for his work in breeding better potatoes, a thornless cactus, and many new fruits. (Consult encyclopedias, the *Readers' Guide to Periodical Literature*, or Beaty, John Y., *Luther Burbank, Plant Magician*. New York: Messner, 1943.)

8-10. Individual or class activities.

11. See *Audubon Magazine* or write National Audubon Society, 1000 Fifth Avenue, New York 28, N. Y. The National Wildlife Federation is at 1129 Vermont Avenue, N. W., Washington 5, D. C.
12. Small bird books are helpful. See Bibliography.
13. Class or individual activity.

UNIT 10. *What Is the History of Living Things?*

Purpose and scope

This unit completes the study of the earth in the *Discovering Our World* series. At this grade level, only an elementary treatment of the history of living things is possible. Pupils should not be expected to learn the names and the time limits of the periods except in a general way. The major understandings to be developed are as follows: (1) Changes in living things have occurred. (2) Millions of years were required for these changes to take place.

Like children, we cannot really comprehend the vast expanse of time dealt with in this unit and in Unit 3 of this book. We must accept it just as we did the vast expanse of space discussed in Unit 7. Scientists have accumulated overwhelming evidence to prove that the earth must be at least 2 billion years old. Recent research on the atom adds further evidence of the earth's great age.

How scientists pieced together countless clues of the earth's dim past to discover the history of living things is as fascinating as a detective story. This unit explains some of the methods used by scientists to obtain evidence from prehistoric times. Accordingly, an important function of the unit is to acquaint pupils with the methods of scientific research. This should lead to further appreciation of the value of scientists' work.

As indicated in *Science Background*, this unit draws on many preceding units of the series. It thus provides an excellent opportunity to apply and extend concepts previously taught. As the study of the unit progresses, these concepts should be recalled, or retaught if necessary.

Science background

Look and Learn: Unit 1, Animals; Unit 3, Days and Days; Unit 4, Outdoors

All Around Us: Unit 1, Animals; Unit 3, Sun, Wind, and Weather; Unit 4, Plants

How Do We Know?: Unit 1, Animals; Unit 2, Land and Water; Unit 3, Plants

Discovering Our World, Book One: Unit 1, How Are the Things of the World Put in Groups? Unit 2, Why Do All Living Things Need Air and Water? Unit 8, How Do Animals and Plants Grow?

Discovering Our World, Book Two: Unit 1, How Do Living Things Help and Harm Each Other? Unit 8, Where Does All the Food of the World Come From?

Discovering Our World, Book Three: Unit 2, Why Does the Weather Change? Unit 3, How Is the Earth's Surface Changed? Unit 7, What Is the Universe Like? Unit 9, Where Do New Plants and Animals Come From?

General concepts

1. The earth is very, very old.
2. Living things have changed during millions of years.
3. New kinds of living things have appeared on the earth as time has gone by; other kinds have disappeared.
4. Fossils show us what living things were like long ago.
5. The study of fossils reveals changes in the earth's surface, in climate, and in living things.
6. The study of fossils shows that living things have developed from simple forms to more complex forms.
7. When changes in the land, the water, the temperature, and the climate occurred on the earth, the animals and plants changed, too.

Introducing the unit (Page 271)

Information for the teacher

PICTURES. PAGE 270. This picture shows several of the giant dinosaurs that roamed the earth during the Age of Reptiles. From left to right these are *Triceratops,* an armor-headed herbivorous dinosaur; *Tyrannosaurus,* the fiercest and most powerful of the carnivorous dinosaurs; one of the bipedal, herbivorous dinosaurs, sometimes called the "bird-footed" dinosaurs; another type of horned, armored dinosaur, *Stegosaurus.*

PAGE 271. A Devonian sea bottom. See the chart, page 100 of this *Guidebook.*

Procedure

To introduce this unit, ask the pupils to recall from Unit 3 what they learned about how the earth's surface has changed. Bring out the length of time that it took for these changes to take place. Have the pupils read the introductory section to check on their answers.

Enlarge on the third paragraph by referring to the picture on page 270. Ask the children to look at the picture carefully and tell how the animals look different from the ones that they see on the earth today. Have the pupils express any ideas that they may have about why these animals no longer live on the earth. Write these ideas on the board and keep the list for future reference.

What were living things like long ago? (Pages 271-276)

Concepts

1. The earth is very, very old.
2. Living things have changed during millions of years.
3. New kinds of living things have appeared on the earth as time has gone by; other kinds have disappeared.

Information for the teacher

PICTURES. PAGE 272. *Left,* animals of the early Paleozoic Era, 500 million to 400 million years ago. The animals with the appendages that look like two feelers are *Trilobites.* These animals were the dominant animals during the earliest of the Paleozoic periods (the Cambrian). A bit later, the large, cone-shaped animals became the largest and strongest animals. They were mollusks called *Cephalopods.* They were giant squids often nearly twenty feet long and a foot across. All the animals of this time were invertebrates, or animals without backbones. *Right,* land flora of the Devonian period of the Paleozoic Era, 350 million years ago. The forests consisted of giant ferns and club mosses, a group of plants closely related to the ferns. The horsetail rush is a common present-day member of this group.

PAGE 273. Cycads.

Page 274. This is *Diplodocus,* the longest but not the fiercest of the dinosaurs. It had very little brain in relation to its size, could not fight well, and was a vegetarian. (The skeleton in the picture on page 277 is from one of these animals.)

PAGE 275. *Left.* The flying reptile is *Pterodactyl.* It had no feathers, and the wings consisted of a wide membrane that connected its forelimbs with its knee and ankle joints. *Right.* The first bird was called *Archaeopteryx.* It had feathers, claws on its wings, and sharp teeth in its jaws. The trees will be recognized as cycads. This is the restoration of the landscape as it probably was in the Jurassic period of the Mesozoic Era.

PAGE 276. *Mesohippus,* the second in the series of horses from which the modern horse developed. The first one, *Eohippus,* was even smaller than this, usually being about the size of a fox. These horses lived during the early part of the Cenozoic Era, which is the era in which warm-blooded mammals became dominant. It is the era in which we now are.

TEXT. Geologic time is divided into eras which, in turn, are divided into periods. In this unit no attempt has been made to present the names of the geologic eras or periods. It is not necessary or desirable for pupils to become involved with these names at this level. However, to enable the teacher to obtain a comprehensive view of geologic history and to present the names for reference purposes, a simplified table showing the eras and the most important periods is given on the next page.

Geologic Timetable

Eras	Periods and How Long Ago They Began	Changes in the Land of North America	Changes in Plants and Animals
Cenozoic	Recent *(50,000 years)*	Glaciers melted Land high above seas Climate warm	Man controls earth Many large mammals extinct Insects increasing
	Pleistocene *(1 million)*	Four great ice sheets covered parts of North America at different times	Saber-toothed tiger, vultures, mammoths, etc. Early man reached Europe Pictures, pages 278, 279
	Pliocene *(12 million)*	Mountains in western United States continued to rise	Horses, elephants, camels almost modern. Mammals migrated
	Miocene *(30 million)*	Mountains began to form Great lava flows in northwest Climate cooler	Mammals dominated Redwood trees appeared in California
	Oligocene *(40 million)*	Land lowered somewhat Climate cooler	Three-toed horses Early elephants Picture, page 276
	Eocene *(59 million)*	Seas covered little of land Climate cooler	Mammals abundant First-known horse—4 toes
Mesozoic	Cretaceous *(130 million)*	Rocky Mts. formed Last great spread of seas over land	Flowering plants appeared Dinosaurs died out at end of period
	Jurassic *(169 million)*	Continents fairly high Shallow seas in western United States	First birds Flying reptiles Dinosaurs dominant animal Pictures, pages 270, 274, 275
	Triassic *(200 million)*	Continents not covered by seas Climate dry	Reptiles dominated Cycads and other gymnosperms First mammals appeared Pictures, pages 270, 273, 274, 277, 287·
Paleozoic	Permian *(235 million)*	Appalachian Mts. as high as Rockies are now	Reptiles were developing Gymnosperms spreading
	Carboniferous *(315 million)*	Greatest coal-forming period Appalachian Mts. began to form	Great coal-forming forests First insects First reptiles Pictures, pages 192, 288, 293
	Devonian *(350 million)*	Seas still widespread over land Climate warm	Lung-fish and first amphibian First forests of fernlike trees Pictures, pages 271, 272, 282, 286
	Silurian *(375 million)*	Seas still covered much of the United States	First air-breathing animals First land plants
	Ordovician *(445 million)*	Seas covered more than 60% of North America	First fishes Greatest development of invertebrates
	Cambrian *(550 million)*	Seas across western United States Climate mild	Trilobites Pictures, pages 272 (left), 284
Proterozoic	Upper Precambrian *(1200 million)*	Mountains formed Great lava eruptions Much sedimentary rock formed	Lime-forming algae Sponges
Archeozoic	Lower Precambrian *(2000 million)*	Mountains were forming all over the world Much volcanic activity Seas small	Blue-green algae Bacteria Probably simple one-celled plants and animals

(See also the summarizing chart on page 290 of the text.) More detailed tables can be found in books on historical geology. *Down to Earth* by Croneis and Krumbein is an especially helpful text for the teacher. The *National Geographic Magazine*, February 1942, has an excellent article, beautifully illustrated, on "The Parade of Life Through the Ages." Consult the Bibliography for further references.

Procedure

The pupils will, of course, have very little accurate information about the living things of the past. To give them an idea of the changes described in the text, make a table like the one below. Have the children read the text down to the last paragraph on page 275 to find out what plants and animals were like during four different periods of the earth's history. When they have this general picture, start the making of a large table on the board.

500 Million Years Ago		350 Million Years Ago		Etc.
Plants	Animals	Plants	Animals	

Ask the children what four divisions they could use to show the changes in living things. They should suggest the four periods given in these pages. Then have the children read again the section on 500 million years ago and look at the pictures. Ask them what kinds of animals and plants lived then and write these on the table. Repeat this for each era until the table is complete.

After the table is completed, have the children study it to find out what important things it shows. Caution them against picking out small details. This part of the lesson gives valuable practice in making generalizations from many details. Write the children's ideas on the board. After they have given their ideas, have them read from the last paragraph on page 275 to the end of the problem to see whether they have given the three important ideas listed there. If not, ask the children to tell how the lists of ideas should be corrected.

Then have the children look at the table and the pictures in the text. Let them tell how they used these to find the big ideas. For example, for Idea No. 1 they may say, "The chart begins at a time 500 million years ago. That shows that the earth is very old." For Idea No. 2: "Trees were once like ferns. At one time, all plants lived in water. Mammals such as horses were very small." For Idea No. 3: "At first there were no plants with flowers, but now there are many. Once there were no mammals." Throughout the discussion, the slowness of the changes should be stressed.

Questions (Page 276)

1. (1) The earth is very, very old. Scientists think that it is at least 2 billion years old. (2) Living things have changed during millions of years. The animals and plants of today are very different from those of long ago. (3) New kinds of living things have appeared on the earth. Other kinds have disappeared.

2. *Page 272, left:* sponges, jellyfish, and animals much like snails. All of these were water animals; they lived 500 million years ago. Plants in that period were all tiny plants that floated about in the water. *Page 272, right:* 350 million years ago you would have seen plants like these—huge, treelike ferns that grew from spores. Flowers had not yet appeared. *Page 273:* 150 million years ago you would have seen trees called *cycads*, which looked like palm trees and which were one of the first kinds of plants to have seeds. *Page 274:* 150 million years ago, in what is known as the Age of Reptiles, you would have seen huge dinosaurs such as these roaming the earth. Some were 100 feet long and weighed almost 50 tons. *Page 275, left:* In this same period you would have seen flying reptiles with long, pointed teeth and wings 25 feet across. *Page 275, right:* 50 million years ago the birds began to look more like the birds of today. *Page 276:* 50 million years ago, horses began to resemble our animals of today.

3. More. Plants changed from tiny water plants to fernlike trees, then to trees with

seeds; and finally flowering plants appeared. Enormous turtles, huge dinosaurs, and flying reptiles disappeared while other animals and mammals similar to ours of today took their places. Early horses about the size of police dogs gradually became like the horses of today.

How do we know what living things were like long ago? (Pages 277-281)

Concepts

1. Fossils show us what living things were like long ago.
2. There are several kinds of fossils.

Experiment

Page 280: To see how fossil prints and molds are made.

Materials: Clay, plaster of Paris, shell or leaf.

Information for the teacher

Pictures. Page 277. This is the skeleton of the dinosaur, Diplodocus, shown on page 274. This skeleton, which is 87 feet long, is in the United States National Museum, Washington, D. C.

Page 278. Animals of the Rancho La Brea tar pits: vultures, saber-toothed tigers, horses in the background. Skeletons of mammoths and wolves were also found in the tar pits.

Page 279. *Left.* The picture of the mammoth is a photograph of one of the very few kinds of large prehistoric animals to be preserved in its entirety. When the mammoths were taken from the ice, even the woolly skins were found to be preserved and in almost as good condition as fresh skins.

Text. Page 280. Petrifaction is not an instantaneous turning to stone as the name might suggest. It is brought about slowly as, molecule by molecule, the materials in the original organism are replaced by the petrifying mineral (usually silica) in the ground water. Since the materials are replaced so slowly, the original shape of the organism is retained. Petrifaction occurs more often in plants than in animals.

Procedure

During the study of this problem and the next one, a trip to a museum is a valuable experience. Many museums will lend collections of small fossils, or perhaps someone in the community has a collection that can be borrowed. Children should be urged to try to find fossils, especially if the school is near a gravel pit or other likely source that is known locally. Encourage pupils to take Saturday hikes to promising regions to obtain fossils. A pile of coal or the debris from a strip coal mine often contains fossils. The gravel on the playground often contains small ones. Some pupil may be able to bring a string of amber beads to class to give the pupils a better idea of the appearance of amber. Such beads, if they are genuine, often contain tiny specks that may be the remains of parts of insects. The fossil collection can be supplemented by pictures and illustrated magazine articles.

To introduce this problem, ask the children to tell about any experiences where they may have seen the remains of ancient plants or animals. Have them look at the picture on page 277 and tell what this shows them about one kind of animal that lived long ago. After this discussion, refer to the fossil fish on page 85 and make sure that the class understands the term *fossil.* Then have the class read pages 277-281 and study the pictures to find out what kinds of fossils there are. The pupils should also do the experiment on page 280.

After the pupils have looked at as many kinds of fossils as possible and at pictures, ask them to list the ways in which fossils are made. If the class has collected enough fossils or pictures, an exhibit may be arranged in which the fossils are classified according to the different kinds on their lists. For activities, see also *Things to Do*, page 294, Nos. 1, 2, 3, and 4.

Questions (Page 281)

1. A fossil is the hardened remains of any animal or plant. By preserving of the whole animal in some material, such as amber or ice;

by being petrified; by preserving bones in tar or layers of rock; by prints or molds in layers of rock.

2. The animals and plants made records that scientists can read. By studying these fossil records, scientists can tell us what these living things were like.

3. Plants often left fossil prints in coal. By studying the fossil print, he could tell us what the plant looked like.

4. No, only partly correct. A fossil is not only the body of a dead plant or animal. It may also be only a part or a print. Or it may be a mold of the animal after the body has decayed.

What have scientists discovered by studying fossils? (Pages 281-284)

Concepts

1. The study of fossils reveals changes in the earth's surface, in climate, and in living things.

2. Fossils were laid down in layers of rock that were formed, one upon another, during the earth's history.

Information for the teacher

Life, September 6, 1947, has an excellent article, fully illustrated, showing the geologic history of the Grand Canyon.

Procedure

This problem is to bring out the reasons for studying fossils. So that the pupils can understand these reasons, it also makes clear how scientists have been able to determine that the oldest layers of rock are on the bottom. This fact is the point of reference from which the scientists work to establish the ages of fossils and interpret the changes in the earth's surface. To open this problem, tell the children that thousands of dollars are spent each year by scientists to find fossils. Ask the pupils if they have any ideas why scientists think that the study of fossils is so important. These ideas should be listed on the board.

Now have the pupils read from page 281 through the second paragraph on page 282 to find more reasons why scientists study fossils. Let the pupils compare these reasons with the ones that they gave and add to the list on the board. The complete list should include: (1) Fossils show what living things were like long ago. (2) Fossils show us how the surface of the earth has changed. (3) Fossils show us how the climate of the earth has changed. (4) Fossils show that living things went through many changes before they became the plants and animals of today. After these reasons have been listed, the discussion should center around *how* fossils show each of them. For example, (1) the bones of dinosaurs show us what some animals that are no longer on the earth looked like. (2) The fossils of birds and reptiles show how much these animals have changed. (3) The fossils of ferns where cold lands now exist show a change in climate. (4) Fossils of water animals in places now dry show ancient seas.

Then have the pupils read the rest of the problem and look at the pictures to find out how a scientist knows that the fossils can tell him that the earth has changed. These pages explain how scientists know that the bottom layers are the oldest layers. As the pupils read these pages, have them recall from Unit 3, pages 62-66, the way in which rock layers are formed. When the pupils understand how scientists know that the oldest rock layers are on the bottom, they will understand that the fossils found in these rock layers are fossils of the oldest living things. They should also see how finding fossils like these oldest ones in layers above newer ones shows that changes have occurred in the earth's surface at this place. For additional activities, see *Things to Do*, page 294, Nos. 5, 9, 10, and 11.

Questions (Page 284)

1. Fossils of giant ferns, cycads, and other plants that grow in warm climates have been found in Greenland; so it must at one time have had a warm climate.

2. Because there have been found in Michigan many fossils of animals like those that now live in warm seas.

3. What animals and plants were like long ago and where they lived; how the earth's surface and its climate changed at various times during the earth's history.

4. In these places, the rock layers of the earth can be clearly seen and studied. In these rock layers, scientists find the fossils of animals and plants that lived long ago.

5. Water drained into seas carrying mud, clay, sand, etc., all of which kept settling to the bottom. Animals and plants died, settled, and were covered. The material turned to stone, and a layer of rock was formed. Each new layer of rock was formed in the same way on top of the lower layer. So the first, or bottom, layer is the oldest. Often after a layer of rock had been formed, the land was pushed up and the water ran off. Then after millions of years, water again covered this land; and a new layer of rock was slowly formed on top of the old layer.

6. (*a*) The rock at the top of the mountain was once under water. (*b*) The desert was once covered by a sea. (*c*) The far north was once under warm, salt water. (*d*) The region once had a warm climate.

How have animals and plants changed? (Pages 285-289)

Concepts

1. The study of fossils shows that living things have developed from simple forms to more complex forms.

2. The complex forms of animals and plants developed from the simple forms during millions of years.

Information for the teacher

PICTURES. PAGE 285. *Top row, left to right,* amoeba, hydra, coral polyps, salamander. *Bottom row, left to right,* flatworm, clam, earthworm, duck. The flatworm (a planarian) looks almost as simple as the amoeba; but it has a head, digestive tract, and simple nervous system, while the amoeba has none of these parts.

PAGE 286. A restoration of Diplovertebron, a primitive amphibian of the coal period.

PAGE 287. The skeleton of an ichthyosaur. The outline of its body was also preserved in the rock. Ichthyosaurs were marine reptiles whose external structure closely resembled present-day dolphins. They were common in the sea in the Mesozoic Era.

TEXT. How these changes in plants and animals were brought about is a question that will probably be asked by some inquiring pupil. In answering this question, the teacher should avoid the implication that some imaginary being, such as Father Time or Mother Nature, sees the need for changes and causes them. One theory advanced by scientists to explain changes through the ages is *mutation.* A mutation is a heritable variation due to a fundamental change in the constitution of the germ plasm, that is, the part of the body in which characteristics are transmitted from generation to generation. These changes take place suddenly and may be brought about in various ways. As a result of some such change, an individual is born with a new characteristic. In prehistoric times, for example, perhaps a fish developed, by a mutation, fins that could be used slightly in walking. A characteristic like this can be passed along to offspring. As generations go by, it is found in more and more individuals. If the new characteristic leads to better adaptation of the individual to its environment, the new individuals become the strongest and most likely to survive. Meanwhile, the new characteristic may develop more fully from generation to generation. Fish may develop legs and lungs—still by mutation, however, and not by actual change in individuals during their lifetime. In this way, the amphibians may have developed from the fish.

Procedure

The first part of this problem develops the meaning of the terms *simple* and *complex*. Use the text and the picture on page 285 to develop the terms. From *Discovering Our World, Book One*, Unit 1, have the pupils recall what they learned about the different groups of animals and plants. When the distinction between *simple* and *complex* has been made clear, the pupils should read the rest of the problem, look at the pictures, and discuss each change thoroughly. During this reading and discussion, emphasize the slowness of the change and the great length of time between the laying down of the different rock layers. Continue the line of reasoning about living things begun in the previous problem. This may be summarized as follows:

1. The oldest layers of rock are at the bottom. Scientists know this because of the way the rock layers were laid down.
2. The fossils found in the bottom layers are the fossils of the first living things.
3. The oldest fossils, found in the bottom layers, are simpler than the ones found in the upper or newer layers.
4. Therefore, scientists believe that the more complex animals and plants have developed from the simple ones.

When the pupils have finished reading and looking at the pictures, have them summarize by making a list of the important ideas presented in this problem. The table made at the beginning of the unit, as well as anything learned from museum visits or collections of pictures, may also be used to help make the list. Pupils' lists should be made into one list on the board and should include these ideas:

1. The first animals and plants were very simple.
2. Living things gradually became more complex and came to be like those of today.
3. Animals developed in this order: animals without backbones, fish, amphibians, reptiles, birds, and mammals.
4. Plants developed from one-celled plants to mosses, then to ferns, and finally to plants with flowers and seeds.

Additional activities will be found in *Things to Do*, page 294, Nos. 6 and 8.

Questions (Page 289)

1. One-celled animals. Because they are the simplest animals. All fossil animals found in the oldest layers of rocks were simple animals.
2. Plants developed from one-celled to many-celled plants; developed roots, stems, leaves, and flowers; developed from mosses to ferns, from ferns to plants with flowers and seeds.
3. It means that fish with backbones seem to have developed from simple animals without backbones; amphibians from fish, and reptiles from amphibians; birds and mammals from earlier animals, possibly reptiles. Plants have developed from one-celled plants to our present plants with flowers and seeds.
4. They had to develop lungs and legs.
5. The animals and plants scientists found in the oldest layers of rock were the simplest; in the layers of rock above the oldest layers, they found animals and plants that were more complex; fossil plants and animals are not exactly like the plants and animals today; the kinds of changes that have taken place show scientists that the living things of today probably developed very slowly from plants and animals of long ago.
6. Today's horses are much larger, have longer ears and heads, longer legs, longer, heavier tails, and more arched necks and backs.

Why have some kinds of living things disappeared from the earth? (Pages 291-293)

Concepts

When changes in the land, the water, the temperature, and the climate occurred on the earth, the animals and plants changed, too.

a) The bodies of some kinds of animals and plants changed in ways that adapted them to their new surroundings.

b) Some kinds of animals and plants moved to new surroundings where they could still live unchanged.

c) Some kinds of animals and plants died.

Procedure

Ask pupils to look back through the unit and find pictures of animals and plants that are no longer found on the earth. Ask them to think of possible causes for the disappearance of these and other living things. What the pupils have previously learned about food, air, water, and temperature requirements for living things, interrelationships, changes in earth's surface, etc., should enable them to have some ideas about the disappearances. Let the children discuss their ideas and then list them on the board.

Now have the children read the problem and study the chart on page 290 to see whether they have thought of the correct reasons and to find additional explanations. Be sure to develop the meaning of the word *adapt* on page 291. Compare the reasons for the disappearance of plants and animals given in the text with the list on the board and make necessary corrections or additions. Compare them, too, with the ideas expressed in the discussion of the picture on page 270. For an additional activity, see *Things to Do*, page 294, No. 7.

Questions (Page 293)

1. Their bodies may change so that they can stay alive in their new surroundings; they can move to a place where they can live without changing; or they die.

2. Answers may include pictures on pages 270-279, 282, 286, 287.

3. Seas changed to land; land changed to sea; land was covered with ice; land lifted to mountains; temperature changed.

4. If all the land was covered with water and then the land pushed up and the water ran off, all the water animals would have to become adapted to their new surroundings. For example, fish developed fins like legs and lungs as well as gills so that they could live on land as well as in water. Water plants also changed so that they could live on land when the seas disappeared. If plants and animals could not adapt themselves or move, they died.

Questions to answer (Page 294)

1. Very few remains of present plants and animals are being deposited under conditions in which they will be preserved. The conditions that formed fossils no longer exist.

2. Because during that age the animals named were the most common.

3. The first birds had sharp, pointed teeth, long, pointed tails with feathers along the sides, and seem to have been much larger than our robins, crows, etc., of today.

4. The earliest fossils are found in the oldest rock layers, which are almost always the bottom layers.

5. The conditions of great heat and force under which igneous rocks are formed would destroy the remains of plants and animals. The conditions under which sedimentary rocks are formed help preserve the remains.

6. The simplest animals lived first. So a layer containing only simple fossils is probably older than a layer containing more complex fossils.

7. They may become adapted to living on land, find another swamp, or die.

Things to do (Page 294)

1. See Bibliography.

2. The text pictures and some of the Bibliography references will help identify these specimens. Knowing the name of the fossil, the pupil can find a description of the habits of the plant or animal. This knowledge may help give ideas about the former appearance of the fossil's surroundings.

3. See Bibliography.

4. Make sure that the children see several types of fossils, that is, prints or molds, shell fossils, amber fossils, skeletons. If there are restorations, such as dinosaur groups, explain that scientists have used their knowledge of ancient animals to build these representations. Be sure that the children do not think that the whole animal was preserved.

5. See Bibliography.

6. Consult the chart on page 290 of the text and use the information in the text to help make this chart.

7. Consult a botany text or an elementary encyclopedia.

8. Use the pictures in the text and references in the Bibliography.

9-10. The *Guidebook* cannot give specific information for all regions, but the principles learned in this unit will apply to any region.

11. See Bibliography and consult encyclopedias. An excellent book about Agassiz for young readers is *Runner of the Mountain Tops* by M. L. Robinson. (See Bibliography.) This may be read by interested readers in the class, or the teacher may use it as a basis for telling the story of Agassiz.

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Part Four MATERIALS AND SOURCES

Care of Living Things in the Classroom

Animals

General suggestions. QUARTERS. Provide roomy and comfortable quarters for every animal—aquaria and terraria (see below) for land and water forms; cages of screen, hardware cloth, or other material for mammals, insects (see below), etc. The cage must be cleaned daily, or a diseased pet will result. *The cage should have a removable bottom for cleaning facilities and stationary containers for food and water.* Line cage with newspapers or other material that may be destroyed. Provide sleeping quarters such as straw or a comfortable box.

WATER. Provide with fresh water daily.

FEEDING. Feed daily. Most wild animals must be trained to eat in new living quarters. Patience is necessary. Try to imitate the living conditions of the animal as they were in its natural environment. Remove surplus food after animal has eaten. Provide plenty of food; the animal will not overfeed. There is no more pitiful spectacle than half-starved animals in a laboratory.

Delicate animals such as guinea pigs should be fed twice daily and at regular times. Early morning and late evenings are best. On Fridays provide enough to last over Sunday. Cold-blooded animals such as frogs, lizards, swifts, turtles, etc., do not require as much food as warm-blooded animals. One feeding a day is ample. A large feeding every other day is sufficient in most cases. In aquaria do not leave uneaten food to foul the water.

Vary diet to prevent weakness and disease. The following food list is suggested.

Snails: Lettuce leaves, aquatic plants, powdered meat, powdered cuttlefish bone.

Fishes: Prepared fish food, chopped beef, particles of earthworms.

Salamanders and lizards: Flies, earthworms, chopped beef, liver.

Frogs: Diet varies with kind of frog. Insects, fruit flies, roaches, earthworms, larvae, chopped beef, very small strips of liver, etc.

Turtles: Overripe fruit, lettuce, clover, carrots, strips of liver.

Snakes: Small frogs, mice, lizards, beef, liver, chicken scraps.

Rats and mice: Table scraps, cheese, wheat flour paste mixed with milk, pinch of salt and lime, dried yeast, lean meat, lettuce.

Guinea pigs and rabbits: Plenty of succulent green vegetables—at least body weight daily. Carrots, turnips, dry sweet hay, clover, different grasses, dry grain, apples and apple parings, apple cores, pear peelings, tomatoes (for rabbits, twigs with bark for gnawing occasionally), water cress, wheat and oat shoots.

The insect cage. Grow some plants from seed-corn, wheat, clover, grass, etc., in a large pot of earth, or transplant weeds or other plants suitable as food for the insects to be kept. Press a large lamp or lantern chimney into the soil, fitting the plants inside it. A small container of water should also be fitted inside the chimney. Place the insects inside the chimney and close the top with wire screening or mosquito netting. When the insects have eaten the food within the container, move it to a new pot of plants.

Ant colonies. It is not difficult to establish ant colonies for observation. The Lubbock ant nest is well adapted for use in the schoolroom since it shows all the tunnels and chambers. Such a nest may be obtained from one of the scientific supply houses listed on page 119 of the *Guidebook*. It is not necessary, however, to purchase an observation ant nest, as one similar to the Lubbock nest can easily be constructed.

Obtain two pieces of glass about twelve inches square. Lay one piece of glass flat on a table and glue one-quarter-inch strips of wood around three edges, using water glass or glass cement. On the fourth side leave two openings. (These openings may be made by using three short pieces of wood instead of a long one. Put one piece at each end of the fourth side and one in the middle. This will leave two openings.) After the glue is dry, fill the frame with a mixture of sifted loam and sand, leaving a space in the center for the ant colony and spaces near the two openings in the frame, which are to be plugged later to keep the ants from getting out.

Ant colonies may be found beneath logs or stones, or in underground nests in gardens and lawns. When a colony has been found, look carefully for a queen or two. The queen can be identified by her large size. (*The National Geographic Magazine* for August 1943 gives the life of ants and shows in pictures the different ant forms.) With a trowel, scrape up a queen and as many of the other ants, eggs, and larvae as possible and take them home in a glass jar with a tightly screwed lid. Place the ants in the center space left in the ant nest. Then glue on the top piece of glass. In one of the holes in the frame place a small sponge, which must be kept wet, as ants cannot be left without moisture. The other hole is for food. Bind all the edges with glass adhesive tape. Then plug the two holes with removable stoppers. Feed the ants from time to time, dropping bits of meat, bread, grains, sugar, drops of honey, and dried insects into the food hole. Keep the frame covered to exclude all light for a day or two. By then, the colony will be established and can be observed.

The aquarium. A square or oblong tank aquarium is the best type that can be had. Lacking that, the ingenious teacher will find many good substitutes, such as large-mouthed battery jars and fruit jars. Globes are not as desirable as other types, for they distort the appearance of animals and break easily. Thoroughly clean sand, natural objects that are found in streams (such as attractively colored pebbles that have been shaped by water action), and the proper kinds of plants and animals are the materials necessary for stocking an aquarium. A small net, rubber tubing for a siphon, and long-handled forceps are desirable.

Setting up the aquarium. Clean the container thoroughly. Put in a one- to two-inch layer of clean sand. Place the aquarium where it is to stay permanently. The most desirable place is one where it will not receive much direct sunlight, but plenty of diffused light, such as near a north window.

The close observer in the field will need no special instruction as to the types of plants desirable for the aquarium. Eel grass, water milfoil, pond weed, water cress, and certain kinds of algae can be collected from the habitat where they are growing and placed in the tank to grow under similar conditions. The florist or pet shop can furnish such cultivated varieties as vallisneria, sagittaria, elodea, ludwigia, etc.

In arranging the plants and natural objects, try to make them resemble a natural pond. Anchor each plant in the sand at the bottom of the aquarium by embedding about an inch of the base of the stem and placing pebbles around the base. The upper part of the plant can then be allowed to lie flat on the sand, as it will straighten to an upright position when the water is put in.

Place a large piece of paper over the plants and the sand, and siphon the water gently in on top of it. The paper will prevent displacing the sand as the water is poured in and should be removed when the aquarium has filled. Use water from a spring or clear stream, as tap water often contains chemicals that are harmful to animal life. Let the aquarium stand for several days until the plants adjust themselves. Then put in the animals.

A good caution is not to overstock the tank. The fish rule is "one inch of fish to one gallon of water." This does not include insects, tadpoles, etc., the number of these depending upon the size of the aquarium. An average amount of animals for one gallon of water is one one-inch fish, one tadpole, one snail, and several water insects. Goldfish should not be used in a school aquarium unless native types cannot be obtained. Use familiar animals that have been collected by the children, if possible. Some native fish that thrive in an aquarium are catfish, mud minnows, sticklebacks, and perch. Snails of the common fresh-water type are desirable as scavengers. Clams and fresh-water mussels should be used if possible. One is usually sufficient for an average tank. Very small turtles (one inch in diameter across the back) may be used. They must be well fed so that they will not disturb other animals. Rocks projecting out of the water must be provided for turtles, so that they can get above the water to breathe. Bullfrog tadpoles and newts or salamanders may be taken from springs and streams. Desirable insects are dragonfly nymphs, back swimmers, water boatmen, water striders, and whirligig beetles.

Feeding. Feed sparingly, once a day on the average, and remove excess food as soon as the animals have eaten. Prepared fish food of several types is easy to use and suits many animals. A worm suspended on a string is a good change of diet. Small flies, water plants, and other natural foods, noted by observing animals' habits, should be provided. See the food list on page 113.

Caution: Watch the aquarium closely. The water may have to be changed often at first. *Animals use the oxygen of the water for breathing, while plants use the carbon dioxide which is a waste product of animal life. Plants make oxygen. In this way the balance of aquarium life is maintained.* Do not overfeed animals. Remove dead animals and plants immediately.

Plants

Pots and window boxes. TEMPERATURE. A daytime temperature of 65-70 degrees and a night temperature of 55-60 degrees is desirable in the schoolroom for normal plant growth. When the outside temperature is excessively low, protect the plants from freezing by placing newspapers between them and the windowpanes.

WATER. Water the plants only when they need it—when the soil is dry. Enough water should be given at one time to wet the soil to the bottom of the pots. Then wait until the soil is dry before watering again. Sprinkle the leaves thoroughly once a week in order to keep them free of dust and soot (with the exception of African violets, whose leaves should not be wet).

PESTS. Plants are frequently attacked on the underside of the leaves by small green lice, mealy bugs, and scales, which are lice with hardened outer coverings. To rid the plants of lice and mealy bugs, wipe the under parts of the leaves with soapy water made with a mild soap. Scales can be removed only by using a toothpick or dull, pointed knife to lift them. Then wash the affected parts with soap solution.

The terrarium. A moisture-tight container such as was used in the aquarium work is best suited to terrarium construction. It should be either square or rectangular because of the better view afforded. If the straight-sided type cannot be had, any glass jar or container may be used. The larger ones are more desirable. Use a piece of plain window glass for a cover.

Almost any plant that grows in the local environment may be raised successfully by simply noting its growing conditions and reproducing them as nearly as possible in the terrarium. Delicate plants that would die in a few days otherwise may be made to live for long periods in a properly regulated terrarium. The secret of success lies in controlling the moisture by means of a tight glass cover. Plants which require little or no moisture may be kept in containers with screen covers, or with glass covers and the presence of little moisture.

The terrarium should be placed where it will receive plenty of light and, if possible, a little early morning sunlight. Care must be taken that it does not receive enough direct sunlight to make the plants "scald" because of too high temperatures. A northeast window is ideal for the average terrarium. The desert type should be placed where it will receive plenty of sunlight for most of the day. Place the container in the location where it is to stay and leave it, as continual moving of the container is bad for both plants and animals.

Ordinary room temperatures are suitable for plants and animals usually found in the vicinity. If the temperature of the schoolroom falls very low over weekends, very little success can be expected. An average nightly temperature of 50 degrees and a daytime temperature of 75 degrees will give good results.

One of several kinds of habitats may be established in the terrarium, but only a few of the most common types will be discussed here. Establish first those that match the environment near the school and those with which the pupils are most familiar. Others may be established to show different conditions as interest grows.

Woodland type. In the bottom of the container, place a layer of sand or coarse gravel about an inch and one-half thick. On top of this, place a layer of loose rich humus from the forest floor. On field trips with the children, select small plants that are found growing in the deep woods. Place in this miniature woodland such animals as may live there. A small salamander (land type) and two small toads will make a good collection. A small snake may be added if desired. Keep the soil moist, but do not allow the water to stand for long periods of time. Feed the animals with small insects such as house flies, worms, and small strips of liver. Keep the terrarium covered with glass. Exclude most direct rays of sunlight.

Marsh type. Place a layer of gravel on a slope, so that it will be about four inches high at one end and about one inch at the other. Cover this layer with rich, moist earth from a bog. Put in plants that require much moisture —mosses (sphagnum is good), small clumps of marsh grass, and similar plants. Place water plants (see directions for aquarium), and put about two inches of water in the lower end. Animals such as small turtles, a small fish or two, a tadpole, small frogs, etc., will complete the animal life. Feed as directed on page 113 and keep covered.

Desert type. Construct this type of terrarium when a study of conditions prevailing in very dry countries is desirable. Use coarse gravel covered with sand as a base. Place small cactus plants of various types in natural positions. Cover the roots completely. Water very sparingly once every two or three weeks, as the plants tend to decay if watered too often. Keep a small pan of water in one corner for the animals to drink from. Animals such as horned toads and fence lizards may be kept successfully. Feed as directed on page 113. Cover the terrarium with screen wire.

List of Materials

The materials needed for the experiments and observations described in the pupil's book are listed below. Many of the items may be brought from home by the pupils. Some may be borrowed from upper-grade science rooms. Others may be bought locally in ten-cent stores, drug stores, hardware stores, pet shops, feed stores, florist shops, greenhouses, etc. It may be necessary to order a few items from supply houses. These items are printed in heavy black type. The names and addresses of the supply houses are given on page 119.

QUANTITY	ITEM
–	Agar, nutrient or potato
–	Algae
1	Balloon, toy
2	Balls: 1 small, 1 large (or use globe)
1	Battery, storage
1	Begonia plant
1	Bell, small electric
Piece	Blotting paper
3	Boxes: 1 chalk, 2 small wood open at one end
Slice	Bread
1	Bucket
1 or more	Bulbs, flower
1	Candle
2 pieces	Cardboard, smooth glossy white
1	Cardboard tube (for periscope)
Few pieces	Cellophane, red, blue, green
2 cups	Clay
2 yards	Cloth, 1 white, 1 dark
2	Coins: 1 penny, 1 half dollar
1 strip	Copper (1 inch wide, 5 inches long)
1	Cord for electric iron
2 pieces	Cork: 1 to fit test tube, 1 smaller
6 wads	Cotton (to plug test tubes)
1	Cup, metal
3	Dishes (1 to grow flower bulb)
3	Dry cells: 2 new, 1 worn-out (No. 6 if possible)
1	Electromagnet
1	Fan, small electric
1	Flashlight
Several	Flowers that show parts
1	Flute
1 or more	Flies, living
1	Fuse, plug-type
4	Glasses (tumblers): 1 thin, 2 thick, 1 any size
4	Glass jars or bottles: 2 small just alike, 1 tall with large mouth, 1 with screw top
1	Glass tube
1	**Glass U-tube**
1	Glider, toy, or model airplane
2 cups	Gravel, clean
–	Heat, source of
1 cup	Ice, chipped
1	Iron, electric (old, worn-out)
1	Ivy plant and/or willow, grape, geranium, poplar
1	Knife, sharp
1	Lamp chimney
2	Leaves, each fresh
3	Light bulbs, 2 small electric, 1 used
Pieces	Magnetic and non-magnetic materials
3	**Magnets:** 2 bar, 1 horseshoe
1	Magnifying glass
1	**Microscope** (optional)
1	Megaphone or piece of cardboard
Few drops	Milk
3	Mirrors: 2 small, 1 large
1	**Motor, toy electric,** with place for attaching color wheel (optional)
2 or 3	Mushrooms
Several	Nails, small
1	Nail or bolt, large
1	Needle and thread
1	Onion bulb
1	Oven, hot for baking petri dishes
1	Pan (to hold 3-4 inches of water and 6 test tubes)
Few pieces	Paper, red, blue, and green (or crayons to color white paper)
Several	Paper, sheets of white

QUANTITY	ITEM
Piece	Paper, brown wrapping (large enough to cover a window)
Pieces	Paper, gummed (for labels and for sealing Petri dishes)
1 dish	Pebbles
6	**Petri dishes**
1	Piano
1 cup	Plaster of Paris
1	Pole, window (or other long)
–	Pollen on blossoms
1	Potato, white
1	**Prism**
1	Push button, electric
–	Refrigeration or means of freezing water
6	Rubber bands: 3 same length and width, 3 same length but different widths, 1 very strong (or elastic)
1	Ruler
–	Sand: enough to fill sand box; some of it coarse
1	Sand table or sand box
1	Saw
1	Saxophone
1	Screen or white wall for use with projector
Piece	Screening, wire
6	Screws
1	Shell
Several	Slides
1	Slide projector (optional)
1	Socket, small electric
Handful	Soil
3	Spools
1	Stick with rubber stopper or cork at one end
2 feet	String
1 tsp.	Sugar
2 tbs.	Sulphuric acid
2	Supports: 1 for bar magnet, 1 for reading glass
Handful	Tacks, iron or steel
8	**Test tubes** of same size
1	**Test-tube rack**
1	Thermometer
2 strips	Tin, ¾ inch wide, 4 inches long
1 strip	Tin foil (about 4-5 inches)
1	Triangle
2	**Tuning forks,** small, alike
–	Twigs
1	Violin
1	Watch
1 bucket	Water
1 glass	Water, muddy
–	Weather reports (newspaper and radio)
2-3 feet	Wire, bare copper
2-3 feet	Wire, covered copper
1 piece	Wire, iron (short)
Block	Wood (about 6 inches long)
2 pieces	Wood, soft (about 8x8x½ inches)
1	Xylophone, toy (with bars that vary in length and width)
1	Yardstick
1	Yeast cake
1 strip	Zinc (1 inch wide, 5 inches long)

Supply Houses

Biological Supply Company, 1176 Mt. Hope Avenue, Rochester 7, N. Y.
Cambosco Scientific Company, 37 Antwerp Street, Boston 35, Mass.
Carolina Biological Supply Company, Elon College, North Carolina.
Central Scientific Company, 1700 Irving Park Road, Chicago 13, Ill.; 441 Clinton Avenue, Newark 8, N. J.; 79 Amherst Street, Cambridge 42, Boston, Mass.
Chicago Apparatus Company, 1735 N. Ashland Avenue, Chicago 22, Ill.
Clay-Adams Company, 44 East 23rd Street, New York 10, N. Y. (models, charts)
Denoyer-Geppert Company, 5235 Ravenswood Avenue, Chicago 40, Ill. (models, charts)
Eimer and Amend, 633 Greenwich Avenue, New York 14, N. Y.
General Biological Supply House, 761-763 East 69th Place, Chicago 37, Ill.
Heil Corporation, 210 South 4th Street, St. Louis 2, Mo.
Marine Biological Laboratory, Woods Hole, Mass.
Millard-Heath Company, 325 Olive Street, St. Louis 2, Mo.
New York Scientific Supply Company, 28 West 30th Street, New York 1, N. Y.
A. J. Nystrom & Company, 3333 N. Elston Avenue, Chicago 18, Ill. (charts)
Oregon Biological Supply Company, 303 N.E. Multnomah, Portland 12, Ore.
Scientific Supplies Company, 122 Jackson Street, Seattle 4, Wash.
Standard Science Supply Company, 1232 N. Paulina Street, Chicago 22, Ill.
Standard Scientific Supply Corporation, 34-38 West 4th Street, New York 12, N. Y.
Tricker, William, Inc., Tanglewood Drive, Independence, Ohio; Saddle River, N. J.
Ward's Natural Science Establishment, Inc., 3000 Ridge Road, East, Rochester 9, N. Y.
Welch (W. M.) Scientific Company, 1515 N. Sedgwick Street, Chicago 10, Ill.

Visual Aids

American Museum of Natural History, Central Park West at 79th Street, New York 24, N. Y. Loans teachers silent and sound films, lantern slides, and cased collections.
Association Films (Y.M.C.A. Motion Picture Bureau): 347 Madison Avenue, New York 17, N. Y.; 19 South LaSalle Street, Chicago 3, Ill.; 3012 Maple Avenue, Dallas 4, Texas; 351 Turk Street, San Francisco 2, Calif.
Bray Studios, Inc., 729 Seventh Avenue, New York 19, N. Y. Films on many subjects.
Bristol-Meyers Co., Educational Dept., 630-C 5th Avenue, New York 20, N. Y. Wall chart showing teeth and their care.
L. W. Brownell, 176 East 32nd Street, Paterson, N. J. Slides on animals, botany.
Encyclopaedia Britannica Films, Inc., 20 North Wacker Drive, Chicago 6, Ill. Films on all subjects. (Has libraries formerly belonging to Eastman and Erpi.)
Films, Incorporated, Education Department: 330 West 42nd Street, New York 18, N. Y.; 611 Tillamook Street, Portland 12, Ore.; 64 East Lake Street, Chicago 1, Ill.; 101 Marietta Street, Atlanta 3, Ga.; 109 North Akard Street, Dallas 1, Texas.
General Electric Company, Educational Service Division, Publicity Department, 1 River Road, Schenectady 5, N. Y. Write for catalog. Motion pictures distributed through local offices.

Keystone View Company, Meadville, Pa. Lantern slides for courses in biology.

Metropolitan Life Insurance Company, 1 Madison Avenue, New York 10, N. Y. Films on medicine, nutrition, safety.

National Audubon Society, 1000 Fifth Avenue, New York 28, N. Y. Lantern slides of North American birds and mammals.

New York University Film Library, 26 Washington Place, New York 3, N. Y.

Santa Fe Film Bureau, 1401 Railway Exchange Bldg., 80 East Jackson Blvd., Chicago 4, Ill. Films on canyons in the west and on locomotives. Free.

Society for Visual Education, Inc., 100 East Ohio Street, Chicago 11, Ill. Films, slides and slidefilms, kodachromes, and charts on all subjects.

U. S. Department of Agriculture
Films: Motion Picture Service, U.S.D.A., Washington 25, D. C.
Information on slides: Extension Service, U.S.D.A., Washington 25, D. C.

U. S. Department of Commerce. *Films.* Catalog of films distributed by Civil Aeronautics Administration, April 1947.

U. S. Public Health Service and, in many cases, your state Board of Health will have a film library or list of recommended aids.

United World Films, Inc., 445 Park Avenue, New York 22, N. Y. (Now owns the large film library of Bell and Howell.)

Visual Aids Service of New Jersey State Teachers College Library, Upper Montclair, N. J. Maintains an up-to-date card catalog and will furnish information relating to suitable audio-visual and teaching aids.

Westinghouse Electric Corp., 306 Fourth Avenue, Pittsburgh 30, Pa. Sends free films and charts on physical sciences and health.

Many public school systems and state universities have departments of visual education which maintain film libraries. State museums often loan slides to teachers.

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BASIC STUDIES IN SCIENCE

Discovering Our World

SCIENCE FOR THE MIDDLE GRADES

by WILBUR L. BEAUCHAMP
MARY MELROSE WILLIAMS
GLENN O. BLOUGH

3

SCOTT, FORESMAN AND COMPANY
Chicago, Atlanta, Dallas, New York

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To the Boys and Girls Who Study This Book

When you opened this book for the first time, what did you do? You wanted to find out what is in the book. So you probably turned the pages and looked at the pictures. You used your eyes to discover something that you wanted to know. Looking at things is one way to find out about them.

How are the boys and girls in the picture learning about airplanes? Some of the boys have made model airplanes and brought them to school. The children in the science class are looking at these planes. They are using their eyes to discover what the parts of an airplane are. As you study this book, you will discover many interesting things in the same way. But you must be sure to look at things carefully or you will not see everything there is to see.

Right now, you are using your eyes in another way to discover something. You are reading the words printed on this page. So reading is another way to find out about things. Suppose you want to find out what you will study in this book. How can you find out quickly? Turn to the Contents on pages 3-5 and read what you see there. As you read, you can discover what is in the book. You are going to learn about sound, the weather, the earth's surface, germs, electricity, and light. You will also study the universe, airplanes, new plants and animals, and the history of living things.

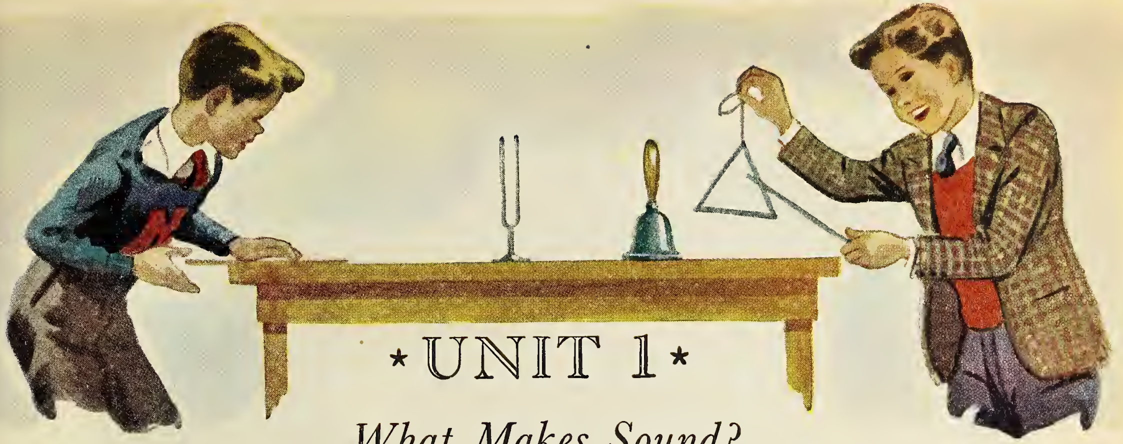
Besides looking at things and reading about them, you will use still another way to discover more about the world in which you live. Scientists have a special name for this other way that you are going to use. They call it experimenting. That means trying things out. When a scientist does an experiment, he wants to discover something that he does not already know. Or he wants to find out whether an idea he has is true.

Did you ever say to yourself, "I wonder how this works" or "What will happen if I do this"? If you found the answer to your question by trying something out, you were experimenting. When a scientist does an experiment, he wants to be sure that the answer is correct. So he does his work very carefully and he does his experiment several times. Here are some good rules to follow as you do the experiments in this book.

1. Always work carefully.
2. Be sure to follow the directions that are given in your book.
3. Watch carefully to see what happens.
4. Think carefully to understand why it happens.
5. Try your experiment more than once so that you can be sure that you do it correctly.

★ *In Unit One You Will Learn* ★

★ How all sounds are alike ★ How living things make sounds ★
★ How sounds travel ★ How we can control sound waves ★
★ Why sounds are different ★
★ How musical instruments make sounds ★
★ How you hear sounds ★



⋆UNIT 1⋆

What Makes Sound?

“When you come to school tomorrow,” the teacher said to her class, “bring something that will make a sound. We will do some experiments with the things you bring to find out how each one makes a sound. I wonder how many different sound makers you can bring.”

The next day the boys and girls came to school with many different sound makers. Then they began to do experiments to discover how each one made a sound. You can try these experiments yourself.

Bill’s sound maker was very simple. He just laid his ruler flat on his desk so that half of it stuck out beyond the edge of the desk. With one hand he held the ruler firmly against the desk, and with his other hand he pulled down on the end that stuck out. “Buzz-z-z-z” went the ruler when he let go of the end. The children looked closely to see what made the sound. But they could see only that the end of the ruler was moving up and down very fast.

Sally and Alice made a sound with a rubber band. Alice stretched the rubber band, and Sally snapped it with her finger. It made a humming sound. Everyone could see that the rubber band was moving rapidly back and forth.

Fred brought the steel triangle that he used in the school band. He held it up by a string and then hit it with a steel rod. The triangle made a ringing sound. When he touched the triangle with his hand, it stopped ringing. Fred said that it tickled his hand when he touched it.

The teacher held up a tuning fork and said, “Who can make a sound with this?” Nancy took the tuning fork and struck one of its prongs on a piece of wood. Then she held the tuning fork near the ears of some of the children. They could plainly hear the singing sound that came from it, but they could not see what made the sound.

Now think about the ways that the sounds were made. You can easily see

These boys and girls made their own instruments. How does each one make sound?

that the things did not make sounds by themselves. A ruler lying on a desk makes no sound. But if you pull one end down and then let it go, the ruler makes a sound. A stretched rubber band makes a sound only when it is snapped. You have to strike a triangle and a tuning fork to get them to make a sound.

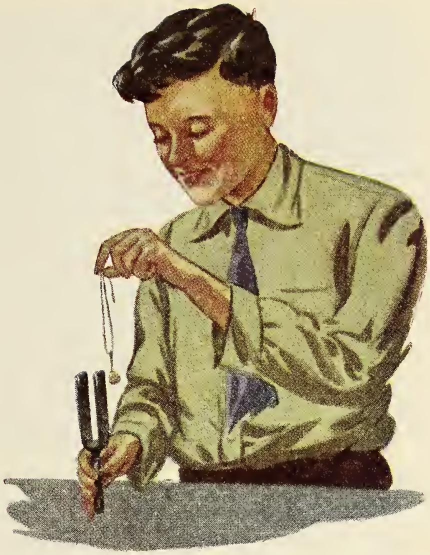
Pianos, organs, horns, drums, violins, guitars, flutes, and other musical instruments are all sound makers, too. What must you do to get each one of these to make a sound?

You probably know that sounds are not all the same. A horn does not make the same sound as a piano or a drum. And you can usually tell which musical instrument is making the sound that you hear. Sounds can be made in many different ways. So you may be surprised to learn that sounds are all alike in one way. Do you know how they are alike?

How are all sounds alike?

YOU KNOW THAT some things make sounds when they are pulled or struck. Now you can do an experiment to see how sounds are made. Be sure to watch closely so that you can see what the experiment shows.

Strike the prongs of a tuning fork on a piece of wood. Then quickly touch some water in a pan with the ends of the prongs. What happens to the water? Why does it spatter? What does this show you about the prongs



of the tuning fork? If you have a triangle, do the experiment again with that. Does the same thing happen to the water this time?

When one science class had done this experiment, some of the boys and girls were quite sure of one thing. They said, "When anything makes a sound, it moves back and forth very fast."

Do you think what they said is true? You can do another experiment that will help you find out. Cut a tiny piece from a large cork. Fasten a piece of thread to a needle and stick the point of the needle into the cork. Then hang the cork near one prong of a tuning fork. Now strike the fork and watch the cork. What makes the cork move? The experiment shows that the prongs of the tuning fork move back and forth very fast. When they do this, the fork makes a sound.

We say that anything which moves back and forth very fast is *vibrating*. The prongs of the tuning fork were vibrating. So was the ruler, and so were the rubber band and the triangle. Each of these things makes a sound when it vibrates. Now you can understand why you have to pull or strike them before they will make sounds. You have to make each one of them start vibrating.

Now try this experiment. Snap a stretched rubber band to make it vibrate and make a sound. Then touch the rubber band while it is still vibrating. What happens? The vibrating stops. When the vibrating stops, the sound stops, too.

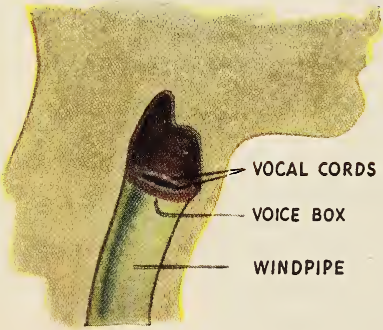
All these experiments show that a sound is made when something vibrates. The ruler, the rubber band, the triangle, and the tuning fork make sounds only when they vibrate. An automobile horn makes a sound when a thin metal disk inside the horn vibrates. Your voice and the voices of your teacher and your classmates are made when something vibrates. The ringing of the school bell is also made when something vibrates. Now do you see one way in which all sounds are alike?

---

1. *What does* vibrate *mean? What are two ways of causing sound makers to vibrate?*
2. *How can you stop a bell or drum that is vibrating and making a sound?*
3. *How are all things alike when they are making sounds? Give some examples to show that your answer is correct.*

How do living things make sounds?

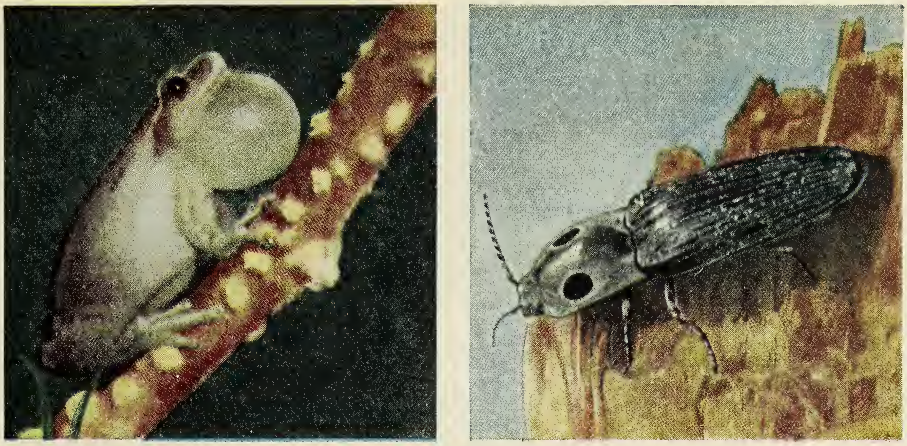
SUPPOSE THAT YOU stand quietly in a woods or in a farmyard. If you listen carefully, you can hear many sounds made by living things. Birds sing, frogs croak, dogs bark, insects buzz, cows moo, pigs squeal, and cats mew. When you tell someone about these sounds, then you are making sounds, too. Do you know how you and other living things make sounds?



Hum a tune. While you are humming, feel your throat. Hold your throat tightly enough to feel it quiver. This tells you there is something inside your throat that is vibrating as you hum.

Inside your throat is a sound box, or a *voice box,* as it is also called. From the voice box come all the sounds that you make when you talk, sing, hum, or shout. Inside the voice box are two parts called *vocal cords.* They are somewhat like rubber bands, and they make sounds in somewhat the same way.

Of course, there is nothing in your throat to snap the vocal cords as you do when you make a rubber band vibrate. Air makes your vocal cords vibrate. The air comes from your lungs as you breathe out. It passes be-



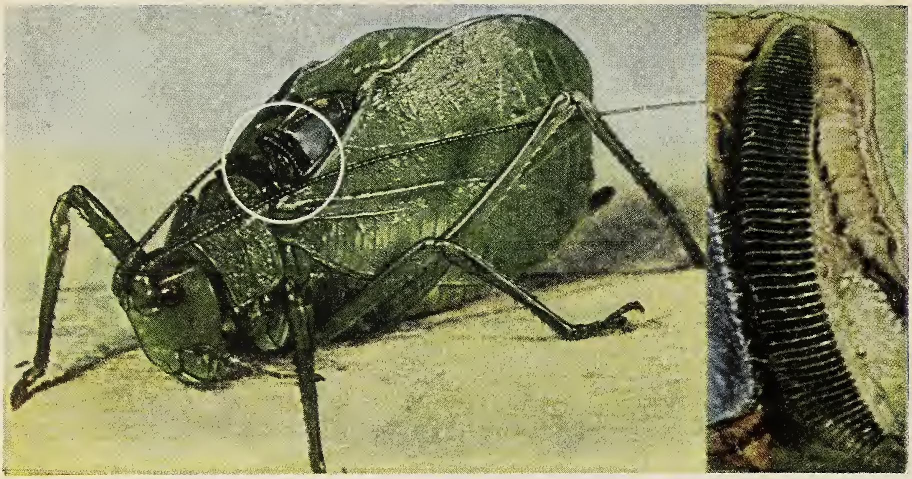
Many frogs have air sacs on their throats. When they croak, they blow out the air sacs. The sacs and the air in them vibrate and make the sounds louder. The click beetle makes a click by rubbing the hard shell of its head against the hard shell of its body.

tween the vocal cords and makes them move back and forth. They vibrate as a blade of grass does when you hold it between your thumbs and blow on it. You can get some blades of grass and show how moving air causes them to vibrate and make a sound. Or you can try blowing on a piece of paper or cellophane as you hold it tightly between your thumbs.

You can make your sounds into words. But you cannot do this with your vocal cords alone. If you want to tell someone something or ask a question, your vocal cords vibrate. You can make high sounds or low sounds and loud sounds or soft sounds just by using your vocal cords. Try it. But you cannot say the alphabet, or any word, with only your vocal cords. Try it. You will see that your teeth, lips, and tongue all help you form the sounds that make words. Your brain helps you talk so that other people can understand you.

Have you ever watched a bird's throat as it sings? Did you see its throat quiver? If you did, then you know that something inside the bird's throat vibrates, too. Birds have vocal cords. These cords vibrate and make sounds when air from the birds' lungs passes between them. You probably know that parrots and some other kinds of birds can be taught to say a few words.

Many animals make sounds when their vocal cords vibrate. But insects have no vocal cords. They make sounds in other ways. Some are drummers, and some are fiddlers. One kind of beetle that lives in old wood has a



In these pictures, you can see the sound file on the edge of a katydid's wing.

strange way of making a sound. It strikes its head against the wood and makes a sound somewhat like beating a drum.

Crickets and katydids have a fiddle and a bow! The male is the musician of the family. Part of one of his wings is rough like a file. Part of the edge of the other wing sticks out. When a male katydid rubs his wings together, he makes a sound like this "katydid—katydid—katydid" or "she didn't—she didn't—she didn't." A male cricket makes a chirping sound in much the same way.

Flies and bees make their humming sounds by moving their wings up and down very rapidly. Hummingbirds also make a humming sound as their wings vibrate.

Animals often use sounds to warn each other of danger. You have probably heard a mother bird sending out sharp cries of warning to her young when a cat came near the nest. Birds seem to use their sounds to call each other, too. No one knows just how much animals can tell each other with their sounds. So far, scientists have not answered this question.

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1. *How does each of these living things make sounds?*
   You Bird Katydid Bee
2. *How are the sounds made by living things all alike?*
3. *What kinds of sounds can we make with just our vocal cords?*
4. *How do we form sounds into words?*

How do sounds travel?

When someone speaks, sounds go from his vocal cords to your ears. How do the sounds do this? From far away and nearby, all kinds of sounds keep coming to your ears. How can they get there? They must travel through the air.

You know that all sounds come from things that are vibrating. These things that vibrate make the air vibrate, too. Scientists call these vibrations in the air *sound waves*. They know that sounds travel in waves through the air. You cannot see these waves. But you can do an experiment to show that vibrations are traveling through the air.

Get two tuning forks that are just alike. Also get two small wooden boxes that are open at one end. Turn the boxes so that the open ends are toward each other. Set the boxes very close together but not touching. Have the room as quiet as possible.

Now hold the handle of one fork tightly against a box. Have someone strike the other fork hard. Use a stick with a rubber stopper or a cork on one end to do this. Then hold the handle of the vibrating fork tightly against the other box. After a few seconds, touch this fork with your fingers to stop its vibrating. Listen carefully. Is the other fork vibrating? How can you tell?

You made one fork vibrate by striking it. The vibrating fork made the air near it vibrate, too. The vibrating air started sound waves. The sound waves traveled through the air to the other tuning fork. When the sound waves struck this fork, they made the fork vibrate. You could not see the sound waves as they traveled through the air. But the experiment showed you that they did travel through the air even though you could not see them. The girl in the picture below can feel the tom-tom vibrate as the boy beats the drum.

Sound waves travel in all directions from a thing that is vibrating. They travel up, down, and sideways. You can do an experiment to show that this is true. Have someone stand in the middle of the room and ring a bell. Walk around the room as the bell is

ringing. Then stand on a chair. Also stoop down near the floor. Can you hear the bell ring wherever you are in the room? What does this show you about how sound waves travel?

If you could take all the air out of a room, you could not hear a thing in that room. Sound waves must have air to travel through. You know that air is a gas. But is air the only material through which sound waves can travel? Perhaps you can answer this question if you read about what happened to some boys.

Jerry and Bob went swimming. While Jerry was diving, Bob was picking up stones in the water and piling them on the shore. Once, just as Jerry dived, Bob bumped two stones together under water. As Jerry came out of the water, he said, "Say, Bob, what made that loud sound in my ears when I was under water?"

The sound was made by the rocks cracking together. What does that tell you about sound traveling in water?

Henry's father always wakened him in the morning. Without saying a word, he told Henry it was time to get up. When Henry's father went to the basement to put coal in the furnace, he tapped three times with the furnace shaker on an iron heating pipe. This pipe went up to a radiator near Henry's bed. When Henry heard the sounds, he woke up. Then he tapped three times on the radiator to tell his father that he had heard the message.

Did the story about Jerry and Bob tell you that water carries sounds? Did the story about Henry and his father tell you that iron carries sounds? You can do some experiments to find out more about how sounds travel in different materials.

Get a yardstick and a tuning fork. Hold one end of the yardstick near your ear and straight out from it. Have someone strike the tuning fork gently to make it vibrate and then hold its handle against the other end of the yardstick. Can you hear the sound from the fork as it travels through the solid stick? Now take away the yardstick. Have someone strike the tuning fork again and hold it a yard away from your ear. Can you hear the sound this time? What does this tell you about solids as carriers of sound? Do they carry sounds as well as gases like air do?

Do the experiment again but use a strip of cloth instead of the yardstick. Hold the cloth out straight as you did the stick. Does the sound of the tuning fork travel easily through the cloth? Soft materials, such as cloth, do not carry sounds so well as wood, iron, and other hard solids.

You know that there are three main kinds of materials in the world. They are called solids, liquids, and gases. All three of them can carry sounds. Air is a gas. Water is a liquid. Iron and wood are solids. Gases do not carry sounds so well as liquids and some solids do. Liquids are better carriers than gases. But hard solids are the best carriers of sounds.

Now can you tell why you can hear the sound of a train far down the track if you put your ear near a rail? Do you know why Indians used to put their ears to the ground to find out if men were coming on horses?

Sound travels very fast. When it goes through air, it travels about 1100 feet in one second, or about a mile in five seconds. It travels even faster than this through water, wood, and metals. Sound speeds through steel at more than 15,000 feet in one second. High sounds, low sounds, loud sounds, and soft sounds all travel at the same speed in the same material.

---

1. *How is a sound wave started?*
2. *If an electric bell is put under a glass jar, you can hear it ring. But if all the air is pumped out of the jar, you can no longer hear the bell ring. Why?*
3. *Tell about an experiment or anything you have done or heard which shows that sounds travel through solids, liquids, and gases.*
4. *Do sounds travel faster in liquids or in hard solids? In liquids or in gases?*
5. *About how long would it take the sound of a loud whistle to travel three miles through air?*

SOUND WAVES travel out in every direction from a thing that is vibrating. But sometimes we want the sound waves to go in one direction only. So we try to guide the sound waves. On this page is a picture of a cheer leader. He is using a megaphone to guide the sounds of his voice toward the crowd. You do something like this when you want to call to someone who is some distance away. You make a cup of your hands around your mouth. When you shout, the sound of your voice is guided where you want it to go.

You can easily make a megaphone out of cardboard and do some experiments. First, have someone stand in a corner of the room and speak very softly without using the megaphone. Then have him speak softly again, using the megaphone. Can you notice the difference? Do you see how the megaphone helps guide the sound of his voice?

Now have someone hold a watch in a corner of the room. Be sure that the room is as quiet as possible. See how far you can get from the watch and still hear it tick. Then have the person hold the watch in the small end of the megaphone. How far away from the watch can you hear it tick now?

You can do these experiments in just the opposite way. Listen with the megaphone instead of sending sound out through it. Put the small end to your ear. Can you hear someone speaking softly in a corner of the room? Can you hear a watch tick? Do you hear better with the megaphone or without it?

The people in the picture on page 19 are noticing something else that is interesting about sound waves. While they are talking, their voices come back to them. The walls of rock *echo* their voices. Have you ever called to someone and heard your voice come back? This sometimes happens when you are between very tall buildings, among hills, or in a big, empty room.

The sound waves of your voice travel through the air, strike a surface, and then are reflected. Reflect

means throw back, as you have already learned. When the sound waves of your voice are reflected, they travel back through the air to you. Then you hear them as an echo of your voice.

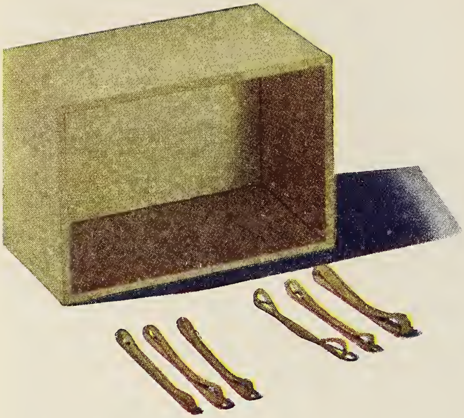
Sometimes you can hear many echoes of the same sound. The sound waves keep bouncing back and forth between the surfaces that reflect them. When this happens in a school auditorium, a church, or a theater, you cannot hear the speaker or music clearly. All the sounds are jumbled together.

Several things can be done to get rid of these echoes. Scientists have discovered how to plan rooms so that few echoes are produced. They know how to use special materials that keep sounds from being reflected. Soft curtains are hung over smooth walls, and rough plaster is put on the ceiling. Materials that are soft or rough do not reflect sound waves well. So they help prevent echoes.

---

1. *How can we guide sound waves?*
2. *People who do not hear well often put their hands behind their ears as they listen. How does this help them hear better?*
3. *How is an echo made?*
4. *Why do we want to get rid of echoes in our buildings? How can we do this?*

Why are sounds different?



HAVE YOU EVER HEARD an orchestra tuning up before it begins to play? If you have, you heard many different sounds all at one time. A violin player picks a violin string with his finger and listens to the sound. Then he tightens or loosens the string and picks it again. The string now makes a different sound. Another player blows on a flute. It does not sound at all like a violin.

The drums make a deep boom, and the horns have a shrill sound. The bass-viol player draws the bow over the strings of his instrument. As they vibrate, they make low sounds. Each player in the orchestra is getting his instrument in tune, or he is "warming up" his instrument so that it will make the sounds he wants.

When the orchestra plays, you hear many sounds. The violin and piccolo make high sounds. The drum and the bass viol make low sounds. You can find out why some of these sounds are high and others are low. Here is an experiment that will help you. Get a chalk box and three rubber bands. The rubber bands should have the same length but different widths. Stretch the rubber bands across the open side of the box. Pick them with your fingers. Do they all make the same sound?

Listen carefully to the sound that the widest band makes. Then listen to the sound of the narrowest one. Which of the bands makes the highest sound? Which one makes the lowest? Which one vibrates most rapidly?

If you did the experiment carefully, you found that the narrowest band made the highest sound and the widest band made the lowest sound. The one that made the highest sound vibrated fastest. The one that made the lowest sound vibrated slowest. When anything vibrates fast, it makes a high sound. The wide band did not vibrate so fast as the narrower bands.

Have you ever seen the strings on a violin, a harp, a guitar, or a cello? The thickest strings make the lowest sounds, and the thinnest strings make the highest sounds. If you have a toy xylophone, bring it to school. Which bars make the high sounds when you strike them? The short bars are thin. They make high sounds because they vibrate so fast. Which bars make the low sounds? The long bars are thick. They make low sounds because they do not vibrate so fast.

Now try another experiment with the chalk box and some rubber bands. This time, use three bands that all have the same length and width. Stretch them across the chalk box as you did before. But stretch the second band tighter than the first and then stretch the third band tighter than the second. Pick them with your finger. Which one makes the highest sound? Which one makes the lowest sound?

When a string is stretched tight, it vibrates faster. So a tightly stretched string makes a high sound. Look at the picture of the harp on the next page. Each string can be tightened to make a higher sound or loosened to make a lower sound. And each string makes a different sound from all the others. Study the picture to see if you can find two reasons for this.

One reason is that some of the strings are thin and others are thick. If you look carefully, you can find the other reason. Do you see that some strings are longer than others? Which ones are longest, the thick strings or the thin ones?

The thickest string is the longest one of all. The thinnest string is the shortest. A short string vibrates faster than a long string. So the short string will make a higher sound than the long one. A short, thin string will vi-

brate very much faster than a long, thick string. So the shortest, thinnest string on the harp makes the highest sound.

When someone is playing a harp, he can make the strings shorter by stepping on the pedals. Stepping down on a pedal pulls a string tighter. So it gets shorter and gives a higher sound.

As boys grow up to be men, their voices usually change from high to low. This happens because their vocal cords become thicker. You know that a thick string makes a lower sound than a thin one does. Girls and women have thinner vocal cords. So their voices are higher.

Besides being high or low, sounds are different in another way. They may be loud or soft. Some sounds are so soft that you can hardly hear them. Others are so loud that they hurt your ears. If you have a toy xylophone, try this experiment. Strike one bar lightly and then hit it hard. Each time, you hear the same sound. But the sound is much louder when you hit the bar hard. The same thing happens if you strike a key on a piano lightly and then hard.

You can do some experiments to find out why some sounds are louder than others. Do the experiment with the ruler on page 9 in two ways. First, pull the ruler down just a little and let it go. Notice how far it moves up and down. Listen to the sound. Then pull the ruler far down and let it go. Watch it move and listen to the sound. Did you see that it moved much farther up and down this time? Which sound was louder?

Now try the experiment with the piece of cork and the tuning fork on page 11 in two ways. First, strike the tuning fork lightly. Notice how far the cork moves. Listen to the sound. Then strike the tuning fork hard and listen to the sound. Did the cork move farther this time? Was the sound louder?

The cork moved farther the second time because it was hit harder by the prong of the tuning fork. The prongs were not moving faster, but they were moving farther as they vibrated. Hitting the fork hard made the prongs move farther back and forth. This made the prong hit the cork with more force.

The farther anything moves as it vibrates, the harder it pushes the air, and the louder the sound is. Anything that is vibrating makes a soft sound when it moves only a small distance back and forth. It makes a louder sound when it moves farther back and forth. If you hit a drum hard, the drumhead goes farther in and then springs back farther. So the sound is loud.

You have learned what makes sounds loud or soft and high or low. You can make your voice change from high to low and from loud to soft. Do you know why you can change the sound of your voice? Look at the picture of the vocal cords on page 12. These two cords in your throat vibrate and make sounds when air from your lungs passes between them. When you are not using your voice, your vocal cords are wide apart and loose. Air from your lungs goes past them without making a sound.

When you talk or sing, the muscles in your voice box stretch the vocal cords. As they are stretched, they are pulled closer together. Air from your lungs passes the narrow slit between the tightly stretched cords. They make a high sound. But if the muscles do not stretch them so tight, the cords make a lower sound. Without even thinking about it, you can tighten and loosen your vocal cords many times every minute that you are using your voice.

When you send air past your vocal cords with more force, you make your voice louder. The cords move farther back and forth. You know that the farther anything vibrates, the louder the sound it makes. When air goes past your vocal cords with less force, your voice is softer.

---

1. *To make a high sound, which of these would you use?*
   Thick string *Long string* *Tight string*
   Thin string *Short string* *Loose string*
2. *Which makes the lower sound, a string that vibrates fast or one that vibrates slowly?*
3. *If you wanted to make a violin string give a higher sound, would you tighten it or loosen it?*
4. *How can you change your voice from loud to soft?*

How do musical instruments make sounds?

CAN YOU NAME the instruments that the boys and girls are playing in the school orchestra in the picture? When the children were learning about sound, they brought their instruments to the science class. They brought a violin, a cello, a drum, a xylophone, a flute, a trombone, a trumpet, and a saxophone. Then each child showed the class how his musical instrument made sounds.

You probably know a few things about musical instruments. You know that some part of each instrument must vibrate to make a sound. And you also know that these instruments can make sounds that are loud, soft, high, or low.

Jack brought his violin to school and told the class about it. He said, "My violin has four strings. You can see that they are not all alike. Some of them are thicker than others. The thick ones make the low sounds, and the thin ones make the high sounds." Jack picked the strings with his finger to show the different sounds.

Then Jack said, "If I want to make a higher sound, I shorten the string. I put my finger on part of the string so that some of it won't vibrate. The part of the string that I press touches the neck of the violin. Only the part between my finger and the bridge of the violin can vibrate. So when I press on the string, I am really making the string shorter. The shorter I make the string, the higher the sound it makes. I can make the sound higher in another way, too. I can stretch the string tighter by turning one of these pegs at the top."

Jack showed the class how he tightened the string to make the sound higher and higher. Then he loosened the string until it made a low, buzzing sound. After Jack tuned his violin, he drew the bow across the strings to make them vibrate. Then he played a tune. As he drew the bow back and forth across the strings, he shortened the strings with his fingers.

Then the teacher opened the piano so that the children could see the inside. They discovered that each key was fastened to a little hammer. When a key is pushed down, the hammer strikes a wire and makes it vibrate. The boys and girls could see that some of the wires were long and thick and others were short and thin.

If the hammer strikes the longest and thickest wire, do you think it will make a low sound or a high sound? Strike the last key at the left end of the piano. This makes the hammer strike the longest and thickest wire. Now strike the last key at the right end of the piano. How is the sound

you hear different from the first sound? Look at the wire that made the second sound. It is the shortest and thinnest wire in the piano. Probably you have heard a piano tuner at work. He tightens and loosens the wires to make sounds a little higher or a little lower.

Jane plays the xylophone in the school orchestra. She showed the class how she strikes the wooden bars with wooden hammers to make the different sounds. Some of the bars are long, and some are short. They are not fastened tightly. Do you know why? Can you tell why drums, triangles, bells, and cymbals all make sounds when they are struck? Each of these instruments makes its own kind of sound.

Here is a picture of Paul with his flute. You can see that it does not have strings. And you know that you do not hit it to make a sound. A flute is a long, slender tube with holes in it. To make a sound, you blow across a hole near one end. This makes the air in the tube vibrate. We call the air in the tube a *column* of air.

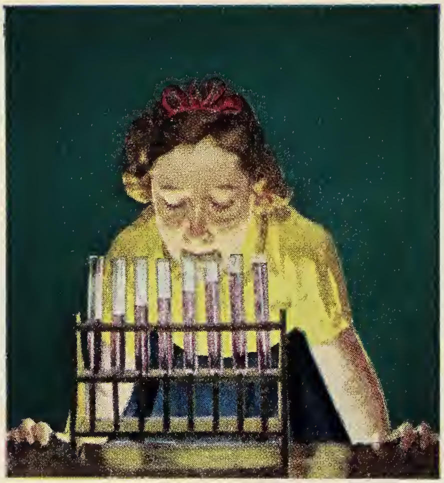
The other holes are covered with little metal covers called *keys*. Paul can make different sounds on the flute by opening or closing these keys. This changes the length of the column of air in the tube. When Paul blows on the flute without covering any of the other holes, the column of air is shortest and the sound is highest. He makes the sounds lower by covering the other holes. To make the lowest sounds, he covers all the holes. This makes the longest column of air and the lowest sound.

Joe plays the saxophone in the orchestra. He told the class how part of the saxophone vibrates when he plays. The vibrating part is called a *reed*. Notice the reed in the picture. Joe has taken the mouthpiece off the saxophone. Then he has taken the reed out of the mouthpiece to show it to the class.

"This reed vibrates when I blow on it," he said. "I can feel it quiver with my lips. The vibrating reed makes the column of air in the saxophone vibrate, too. I can change the sound from high to low or from low to high by changing the length of the column of air. I push down and let up on these keys to do this."

An experiment will show you how long and short columns of air make different sounds. Do the experiment carefully. Get eight test tubes and put different amounts of water into them. If you cannot get test tubes, use small bottles that have the same size and shape. Blow gently over the top of each tube. Do they make different sounds? Which tube or bottle makes the lowest sound? Which one makes the highest sound?

The picture on the left shows Jane and her xylophone. In the other picture, Joe is showing the parts of his saxophone.



Add or take out some water in each tube until the tubes look like the ones in the picture. The column of air over the water will be different in each tube. If the columns of air have just the right lengths, you can make the different sounds of the musical scale. Try to play a tune with the tubes.

The test tubes in the picture do not all have the same amounts of air in them. The tube on the left has the longest column of air. It makes the lowest sound. The tube on the right has the shortest column of air. It makes the highest sound.

Now you can understand how a flute or a saxophone makes different sounds. When the column of air is long, the instrument makes a low sound. When the column of air is short, it makes a high sound. Closing the holes in the tube makes the column of air longer and the sound lower. Opening the holes makes the column of air shorter and the sound higher.

In an orchestra, there are several other instruments that use columns of air to make sounds. The trombone player slides part of his instrument back and forth to make the column of air longer or shorter. The trumpet, the cornet, and the tuba have valves to change the length of the column of air.

You cannot play any one of these instruments just by blowing through it. You have to do something to make the column of air vibrate. If you ever tried to play a trumpet or a bugle, you soon found that you had to hold your lips just right to make a sound. You must hold your lips tightly against the mouthpiece and press them together. When air comes through your lips, they vibrate. Your vibrating lips make the column of air vibrate. This makes the sound. By making your lips tight or loose, you can change the way that they vibrate. Then the column of air vibrates differently, and the instrument makes different sounds.

1. *Name five musical instruments that make sounds with vibrating strings.*
2. *Explain how a piano makes high sounds and low sounds.*
3. *What three things did Jack know that helped him explain how his violin made different sounds?*
4. *Could Jane play a tune on her xylophone if all the bars had the same length and thickness? Why?*
5. *What two ways does a trumpet player use to make different sounds?*
6. *Could you play a saxophone that had no reed? Why?*

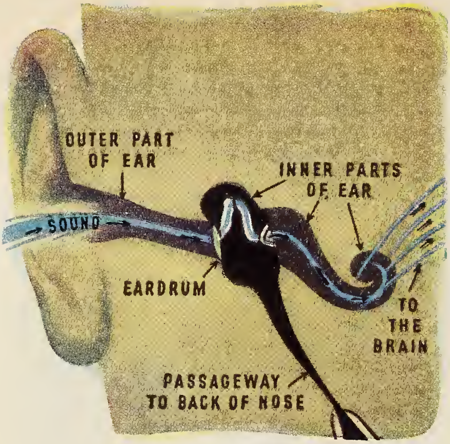
How do you hear sounds?

YOUR EARS CATCH many different sounds. You hear voices, whistles, bells, musical instruments, automobiles, and many other things. Your ears are partly outside your head and partly inside. The outside part is shaped so that it acts like a funnel to catch sound waves. Have you ever noticed how dogs, horses, and rabbits hold their ears up to catch sound waves better? Cup your hand and hold it behind your ear. How does this help catch sound waves better?

Inside your ear is a piece of very thin skin. It is at the end of the opening that goes into your head. This piece of skin is stretched over the opening like the head on a drum. As you know, we call this piece of skin the eardrum. Behind the eardrum, there are three tiny bones. They are fastened together in such a way that they can move. The end of one bone is attached to the eardrum.

The outside part of your ear catches sound waves. These waves go inside your ear, where they strike the eardrum and make it vibrate. It vibrates just as fast or as slowly as the thing that made the sound. Every time the eardrum vibrates, the tiny bones vibrate, too. They vibrate just as the eardrum does. The vibrating bones make other parts inside your ear vibrate. Nerves carry a message from these vibrating parts to your brain, and you hear. The parts inside your ear all work together with your brain so that you hear sounds and understand what they mean.

How can you tell where a sound comes from? Try this easy experiment. Have three or four boys and girls stand in different parts of the



room and make sounds. Close your eyes and listen. Can you tell where the sounds are coming from? Without seeing, you can often tell who or what is making a sound. Your ears and your brain work together to help you tell what kind of sound you are hearing and where it is coming from.

You know that you should take good care of your ears. Here are some rules that will help you if you will remember to follow them.

Safety rules for the care of your ears

1. Never put anything sharp or pointed into your ears. It may break the eardrums.
2. Never use anything sharper than your finger wrapped in a washcloth for cleaning your ears.
3. Never let anyone shout or blow into your ears. Shouting or blowing may injure the eardrums.
4. Never let anyone hit you on your ears. Hitting your ears may break your eardrums.
5. Do not blow your nose too hard when you have a cold. You may force germs into your ears.
6. Swim only in water that you know is clean enough for swimming. Water that is not clean may carry germs into your ears.
7. Be careful not to put sand or dirt into your ears.
8. See a doctor if there is anything wrong with your ears.

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1. *How does the shape of the outside part of your ear help you hear?*
2. *Why is* eardrum *a good name for that part of your ear?*
3. *If you could not hear clearly what people are saying, which of these would you do? Why?*
   - *a) Ask people to speak louder.*
   - *b) Go closer to people who are speaking.*
   - *c) Have a doctor look at your ears.*
4. *Soldiers who shoot big guns usually put cotton into their ears. Why do you think that they do this?*

QUESTIONS TO ANSWER

1. Make a list of some of the different sounds you heard today. For as many of these sounds as you can, tell what vibrated to make the sound.

2. Can sounds travel around corners? How could you do an experiment to help you find out?

3. Why do we not hear a sound unless something is vibrating?

4. Why does a bell make the same sound every time you ring it?

5. Bob set his radio on a table that had a metal top. Whenever the radio was turned on, a harsh sound came from the metal top. Why did the table top make the sound? What could Bob do to stop it?

6. If you drive a pin into a block of wood and pick it with another pin, it will make a sound. How could you drive eight pins into the block so that each would make a different sound?

THINGS TO DO

1. Get some crickets, katydids, or other insects that make sounds. Try to find out how each one makes a sound.

2. If you have an old mouth organ, or harmonica, take off the cover and play the instrument. Which parts make the high sounds? Which ones make the low sounds?

3. Say the alphabet and try to tell which letters are made with the lips and tongue.

4. Make a box harp by stretching rubber bands of different widths across the open side of a box. Stretch some of the bands tighter than others.

5. Play a Sound Game. Have two or three boys and girls take different sound makers behind a screen. Have the other children try to tell what is making each sound.

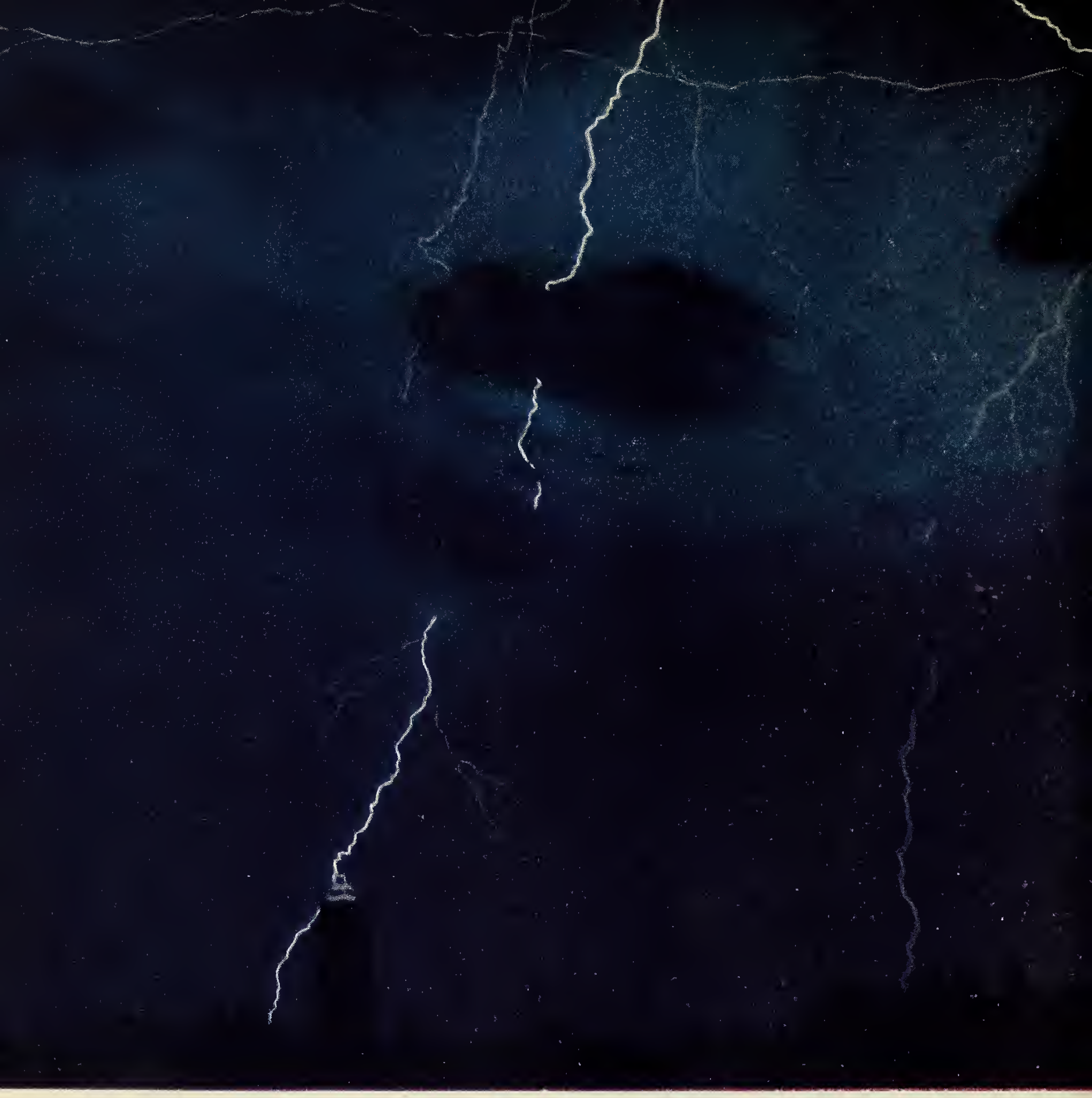
6. Make whistles and flutes out of dried weed stems, cornstalks, or willow branches.

7. Use four flowerpots of different sizes to make a set of chimes. Put small ropes through the holes in the bottoms. Knot the rope inside and hang each pot separately. Strike the flowerpots with a wooden hammer.

8. Make musical glasses by putting different amounts of water into them. Use six or eight glasses. Fill the first one full and leave the last one empty. Tap the glasses with a spoon. Which one makes the lowest sound? Which one makes the highest sound?

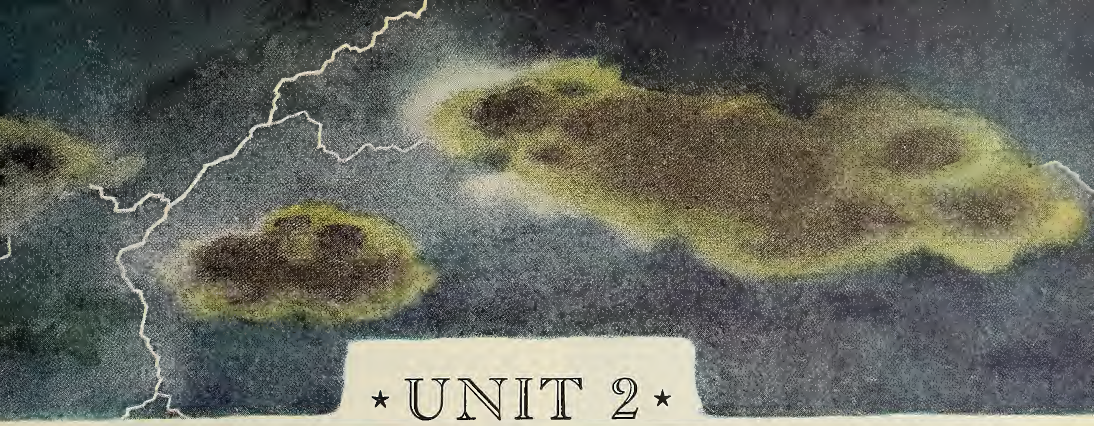
9. Make a toy telephone with two tin cans and several yards of string. Punch a hole in the bottom of each can. Put one end of the string through the hole and tie a knot so that the string will not slip out. Stretch the string until it is tight. Talk into one can while someone listens with the other one.

10. Find out why a giraffe cannot make sounds.



★ *In Unit Two You Will Learn* ★

★ *What we mean by weather* ★ *Why the air gets warmer or cooler* ★
★ *What makes the wind blow* ★ *Why the sky is clear or cloudy* ★
★ *How the water comes out of the air* ★
★ *What the weatherman does* ★ *How weather forecasts help us* ★



★ UNIT 2 ★

Why Does the Weather Change?

JACK FROWNED as he turned away from the window.

“What’s the matter, son?” asked his father.

“Well,” Jack answered, “last Saturday Bill and I planned to eat our lunch in the woods. But it rained all day. Unless the weather changes, we can’t go tomorrow, either.”

“Don’t worry, Jack,” his mother called from the kitchen. “The man on the radio just said it’s going to be warm and sunny tomorrow.”

“That’s right,” added his father. “The evening newspaper says the weather will be fair and warmer.”

Probably you have often wondered what the weather was going to be. Sometimes you wanted the weather to change. And other times you wanted it to stay the same. If the weather was bad, you had to change your plans. Perhaps rain kept you from playing outdoors. Or sudden warm weather melted the ice on a pond, and you could not go skating. Or you could not go swimming because the weather turned colder.

We often wish that we could have just the kind of weather we want. But no one has ever been able to control the weather. Someone once said jokingly, “Everybody talks about the weather, but nobody does anything about it.” Of course, no one can change the weather. But scientists can do something that helps us very much. They can tell us what the weather is likely to be.

For many years scientists have studied the weather, and they know why it changes. They can tell us when it is going to change. And they can also tell us the kind of weather that is probably coming. Then we can make our plans to fit the weather.

As you study this unit, you will learn some of the things scientists have found out about the weather. You will also learn how they use what they have discovered. But first of all, let us find out what weather is.

What do we mean by weather?

Suppose someone in another town called you up on the telephone and asked about the weather where you live. Perhaps you would answer, "It is cloudy and cold. It is raining. A strong north wind is blowing." Or you might say, "The sky is clear. It is hot and dry. There is hardly any wind."

What are you telling about when you describe the weather? Here is a good way to find out. Have some members of your class cut out weather reports in the newspapers. Have other members write down weather reports they hear on the radio. Bring all the reports to class. Then make a list of all the words used in these reports to describe the weather. Write the words on the blackboard. Here are some of the words in a list that one class made.

Clear
Warmer
Gentle winds
Rain
Cloudy
Cooler
Fair
Hot
Strong winds
Mild
Showers
Partly cloudy
Snow
Cold
Fog
Frost

Now look at the words in the list you made or in the list on this page. You can see that the words tell things about the air. So the air must have something to do with the weather. When we use words such as clear, cloudy, hot, and cold, what is it that is clear or cloudy, hot or cold? It is the air. When we tell about the condition of the air, we describe the weather. We often say the sky is clear or the sky is cloudy. But we are really talking about the air that is above the earth. For weather is the condition of the air around the earth.

If you want to describe the weather, there are several things you do. You look at the sky to see if it is clear or cloudy. You find out what the temperature of the air is. Is it hot, cold, or mild? You notice whether any moisture is falling. Is there rain, snow, fog, or frost? You also notice whether there is any wind. Is it strong or gentle? Then you find out from what direction the wind is blowing. If it blows from the south, we call it a south wind. If it blows from the north, we call it a north wind, and so on. When you put all the things you have found out together, you can describe the weather. What kinds of weather do the pictures on these pages show?

Of course, what you say about the weather today will probably not be true tomorrow. It may not even be true a few hours after you say it! Sometimes we say that a person is as changeable as the weather. We mean that you can never tell what the person will do. He may change his mind suddenly and often. The weather changes suddenly and often, too. It may change several times in one week or even in one day.

Keep a record of the weather for several weeks, and you can see how often the weather changes. On the blackboard make a big chart like the one on this page. You will probably find that clear weather changes to cloudy weather and then back again to clear weather. There will be warm days and cool days. Some days will be wet, and others will be dry. You will notice that the strength and direction of the wind change, too. These changes are all changes in the air, and they make the different kinds of weather.

WEATHER CHART

DATE	CONDITION OF THE SKY	TEMPERATURE OF THE AIR AT 10 A.M.	MOISTURE FALL	STRENGTH AND DIRECTION OF THE WIND
Oct. 20	Cloudy	62 degrees	Rain	Strong northwest
Oct. 21	Clear	54 degrees	None	Gentle southwest

1. *Describe the weather today. Use words like those in the list you made or in the list on page 34.*
2. *What changes have there been in the weather since a week ago?*
3. *If the air always stayed the same, would the weather change? Why?*
4. *A boy described the weather one day as "cold and windy." Did he describe the weather well? Explain your answer.*

Why does the air get warmer or cooler?

A WEATHER CHART such as the one above shows you how much the temperature of the air changes from day to day. But a record of the temperature as it changes during each day will probably surprise you even more. Take the temperature of the air three times a day—in the morning, at noon, and in the late afternoon. If you live in a city, the newspapers probably give a weather report at different times of the day. You can get the high and low temperatures for each day from the weather report. Keep a record of the temperatures each day for at least a week. You may find that the temperature changes more than 20 degrees in just one day!

But why does the air get warmer or cooler? Before you can answer this question, you must learn how the sun warms the earth's surface and the air around the earth. You can do an experiment that will help you find out. Remember that you are trying to discover how the sun warms the air.

Get two small glass jars that are just alike. Make one of them black. You can do this by holding the jar in a candle flame, or you can use black paint. Be sure that the paint is dull so that the black jar will not be shiny. Now fill both jars with water. With a thermometer, take the temperature of the water in each jar. It must be just the same in both jars. Then set the jars side by side in the sunlight. After an hour, take the temperature of the water in each jar again. In which jar is the water warmer?

You found that the water in the blackened glass jar became warmer than the water in the clear glass jar. Why did this happen? Both jars were in the sunlight. And both jars got the same amount of energy from the sun. When the sun's rays struck the blackened glass jar, they could not go through the blackened glass. Most of the energy in these rays was changed to heat. This made the glass warmer. The warm glass made the water in the glass jar warmer, too. But when the sun's rays struck the clear glass jar, they passed right through the glass and the water. Very little of the energy in the rays was changed to heat. So the water in the clear glass jar stayed about as cool as it was when you put it into the jar.

This experiment helps you see how the sun's rays heat different kinds of materials. When the sun's rays pass through a clear material, such as air, water, or clear glass, the material is heated very little. But when the sun's rays strike a material they cannot pass through easily, the material is heated much more. The energy in the sun's rays is changed to heat when the rays strike materials through which they cannot pass.

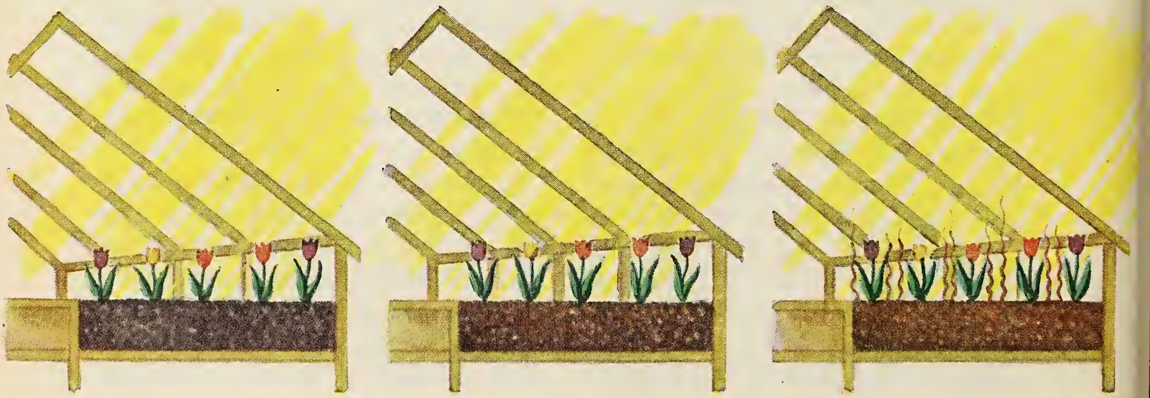
If the sun is shining through your window now, stand in the sun's rays for a few minutes. Do you get warmer? Now feel the window glass. Did the sun's rays warm the glass? Feel the window sill. Is it warmer than the window glass? From what you have just learned, you should be able to explain why you got warmer but the glass did not. When the sun's rays pass through the air, they heat it even less than they heat the glass. On a hot day, you probably have noticed that the sidewalks and the streets are much hotter than the air.

You know that the sun's rays do not heat the air very much as they pass through it. But when the sun's rays strike the earth's surface, most of the energy in the rays is changed to heat. The soil, the rocks, and the water are heated much more than the air. Then the warm soil, the warm rocks, and the warm water give some of their heat to the air above them. The more heat the earth's surface gets from the sun, the warmer the air above the surface will be. Now you can see how the air is warmed.

But why does the temperature of the air change from time to time? Of course, you know that the earth's surface is heated only when the sun shines on it. So the air is usually warmer in the daytime than at night. As the earth turns around, only half of its surface is toward the sun at one time. During the daytime, the place where you live is on the side of the earth that is toward the sun. It is heated by the sun's rays. But at night, this side of the earth is away from the sun. It gets no heat from the sun. It loses heat, and the air gets cooler.

The air is warmer in summer than it is in winter. One reason for this is that there are more hours of daylight in summer than hours of darkness. The sun shines longer on our part of the earth, and the air is warmed more. In winter, we have more hours of darkness than we have hours of daylight. The sun shines less on our part of the earth, and the air is not warmed so much.

The yellow lines are sun's rays. The red lines show heat. Explain how the sun's rays can warm the greenhouse.



A change that takes place in the sky may also change the temperature of the air. On a hot summer day, you have probably wished that it would get cloudy so that you would not be so warm. Or on a cold winter day, you may have wished for a clear sky so that you would not be so cool. Clouds shade the earth just as a tree shades us. When clouds come between the sun and the earth, they keep some of the sun's heat away from the earth.

The air is also warmer in some places on the earth than it is in others. It is warmest over the places where the earth's surface is warmest. In the daytime, the air over land is warmer than the air over water. The sun's rays do not warm the water so much as they do the land. But land cools off faster than water. So at night, the air over water is often warmer than the air over land along the shore. The air above a forest is often cooler than the air above the land near a forest.

You know that some parts of the earth are always hotter than others. And some parts are always colder than others. If you travel south from where you live, you are usually going toward a warmer place. And if you travel north, you are usually going toward a cooler place. A wind that blows from the south is usually warm. A wind that blows from the north is usually cool. The direction from which the wind blows makes a difference in the temperature of the air.

When the wind changes its direction, the temperature of the air usually changes, too. If you live near a big lake or the ocean, the water may help change the temperature of the air over the land. In the daytime, the water is usually cooler than the land. If the wind blows from the water to the land, the temperature of the air over the land may get cooler on a sunny day. So the ocean or lake may help keep you cool on a hot day.

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1. *What kinds of materials are warmed most by the sun? What kinds are warmed least?*
2. *Make a list of the things that you think the sun heats very much. Make another list of things that you think it heats very little.*
3. *How is the air around the earth warmed?*
4. *During an entire day of twenty-four hours, what changes in the temperature of the air usually take place?*
5. *When the sun shines, is the air warmer over water or over land along the shore? Explain your answer.*
6. *Why does the air sometimes get cooler during the daytime?*
7. *Give as many reasons as you can to explain why the temperature of the air changes.*

This picture was taken during a hurricane. The wind is bending the trees and sending high waves up onto the shore. What does this tell you about the wind?

What makes the wind blow?

One autumn day, Bill was raking up leaves in his yard. "This is a good day to do this," he thought as he raked the leaves into piles. "There isn't any wind."

Just then, a sudden puff of wind hit the piles of leaves. Another puff came and then another. Soon the leaves were all over the yard again.

"You might as well stop raking," his mother called from the house. "If this wind keeps on blowing, it won't be safe to burn the leaves. They might set fire to something else."

Wind is just moving air. When air or anything else moves, a force makes it move. If you pick up a book, the force of your muscles moves the book. The force of exploding gas moves an automobile, and the force of expanding steam moves a steam engine. The force that makes air move is the greatest force in the world. Do you know what it is?

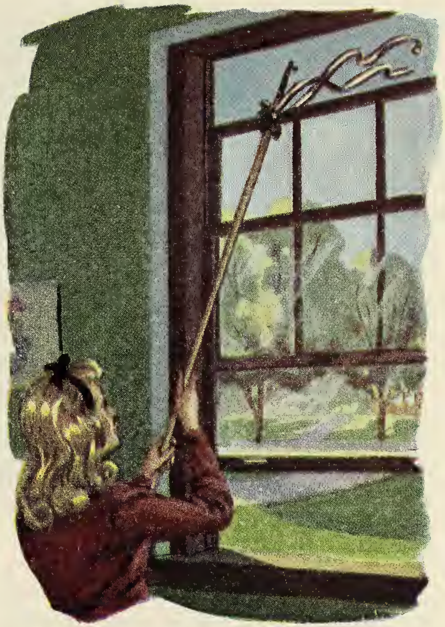
A basketball or a volleyball filled with air weighs more than it does with all the air let out. So does a bicycle tire or an automobile tire. Air is a material, and like all materials air has weight. Air weighs more than you may think. If you could put a block of air three feet long, two feet wide, and two feet high on the scales, it would weigh about one pound. The air in your schoolroom probably weighs more than 1000 pounds!

When we weigh anything, we are really measuring the pull of gravity on it. Gravity is the greatest force in the world. It pulls down on you and on everything else. Suppose your weight is 75 pounds. That means gravity pulls down on you with 75 pounds of force. Air has weight, too, because the force of gravity pulls down on it.

You can do an experiment to see how the force of gravity makes the air move. Tie some strips of paper or cloth to the end of a window pole. Open one of the windows in your schoolroom at both the top and the bottom. Hold the strips near the top opening of the window. Does the air move in or out? How do you know? Now hold the strips near the bottom opening. Which way does the air move this time?

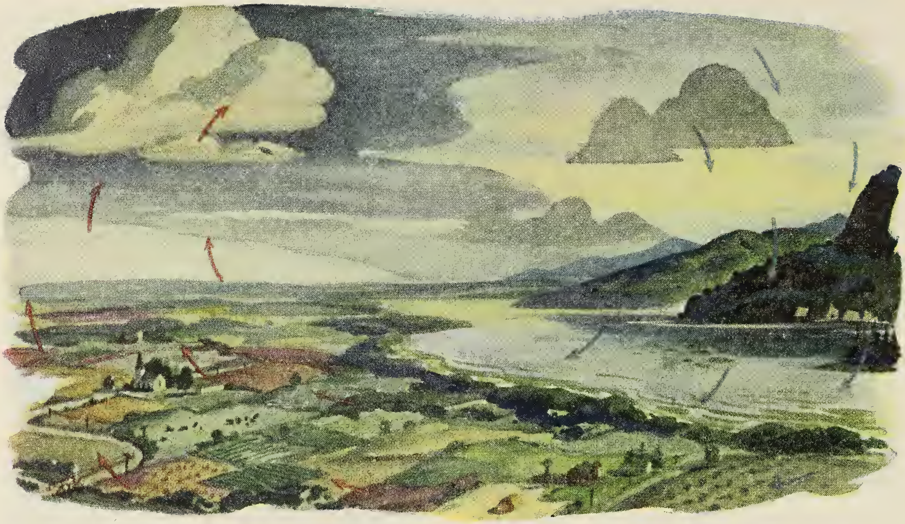
By watching the strips, you could tell which way the air moved. It went out at the top of the window, and it came in at the bottom of the window. If you remember what you learned about gravity and heat, you can explain why the air moved as it did.

Air expands when it is heated. And air contracts when it is cooled. When air expands, it gets lighter. When air contracts, it gets heavier. What will happen if air is cool at one place and warm at another place? Look at the picture on this page. Gravity pulls down with more force on the cooler, heavier air than it does on the warmer, lighter air. The cool air sinks and pushes the warm air up.



The air outdoors is cooler than the air in your schoolroom. Cool air comes in at the bottom opening of the window. This cool air pushes the warm air in the room up and out at the top opening of the window. When air is cool at one place and warm at another place, the cool air pushes the warm air up. Gravity is the force that makes the air move.

The air is always warmer at some places on earth than it is at other places. You know that the temperature of the air where you live changes from day to day. And it usually changes during the day, too. You can use what you know to explain why the wind blows.



Suppose that you are standing high up on the side of the mountain in the picture on this page. Below is a big valley. In one part of the valley, there are meadows and fields. In another part, there are forests and a big lake. Imagine that you can see all of the air in the valley. It is early in the morning. The air is cool and still. But soon the air is going to move and make a wind. Watch and see what makes the wind blow.

The sun slowly comes up and shines on all parts of the valley. Its rays strike the soil and grass in the fields and meadows. Most of the energy in the rays is changed to heat. The soil and grass become warm. They give some of their heat to the air above them. As the air is warmed, it expands and gets lighter.

The sun's rays also strike the forests and the lake. But they are not warmed so much as the meadows and fields. So the air above the forests and the lake is cooler than the air above the fields and meadows. This cooler air is heavier than the warmer air in other parts of the valley.

The heavier, cooler air pushes out against the lighter, warmer air. And the warmer air is forced up. Now the air is moving in the valley—down, out, and up. A wind is blowing along the ground. It blows from where the air is cooler and heavier to where the air is warmer and lighter.

Winds blow because different places on the earth's surface are heated to different temperatures. Gravity pulls with more force on cooler air. The cooler air pushes against the warmer air and makes it move. This causes a wind.

If there is only a little difference in temperature between two nearby places, the air moves slowly. So the wind is gentle. But if there is a big difference in temperature, the air moves faster. Then the wind is strong.

1. *Which of these statements explain why the wind blows?*
    - *a) Gravity is the greatest force in the world.*
    - *b) Cool air is heavier than the same amount of warm air.*
    - *c) Cool air moves faster than the same amount of warm air.*
    - *d) Warm air is hotter than cool air.*
    - *e) Different places on the earth have different temperatures.*
2. *What makes the wind blow hard?*
3. *Near a big lake or the ocean the wind often blows from the water to the land in the daytime, but it blows from the land to the water at night. Why does this happen?*
4. *A forest fire often starts a wind that helps spread the fire. How is this wind started?*

Why is the sky clear or cloudy?

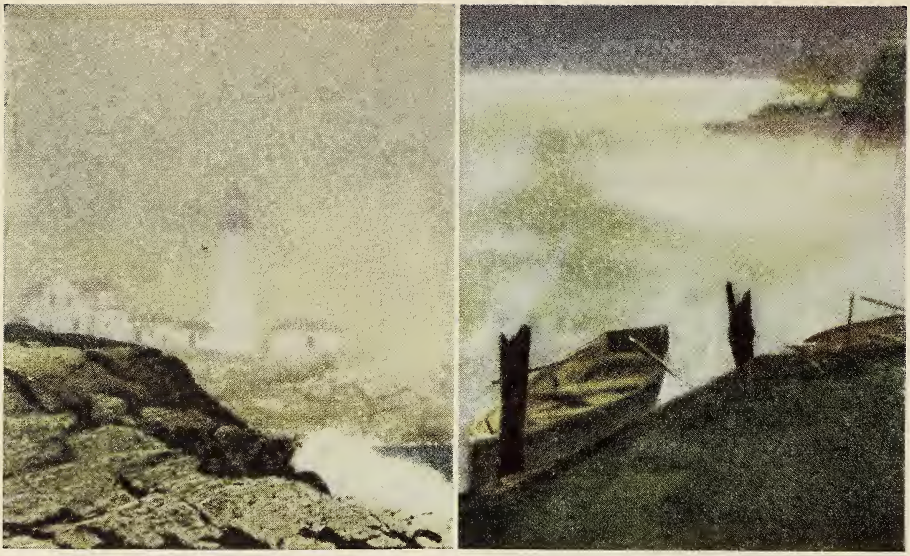
EVERY MORNING when you get up, there is something you can easily notice about the weather. You may not know if it is warm or cool until you go outdoors. You probably cannot tell if the wind is blowing unless you hear it or see the trees move. But as you look out of your window, you can quickly see the condition of the sky.

Some days it is sunny and bright. The sky is clear, or there are only a few little clouds. Some days it is dark and gloomy. Big clouds hide the sun, and they shade the earth from its rays. Then other days the sunshine comes and goes as the clouds pass by. Is the sky clear or cloudy today?

The condition of the sky changes from day to day. It often changes during the day, too. In the morning, the sky may be clear. But after a time, clouds begin to gather. Or the day may start with clouds covering the sky. Then in a few hours, the sun comes out. Before long, the sky is clear.

You have seen the condition of the sky change many times. But do you know why the sky is sometimes clear and why it is sometimes cloudy? Before you can answer these questions, you must first find out how a cloud is made.

An airplane often flies through a cloud. And people sometimes pass



A thick fog almost hides the lighthouse in the picture on the left. The other picture shows water that has come from the surface of the lake and condensed to form a mist. Why do you often see mist over lakes and streams early in the morning?

through clouds as they climb a high mountain. If you have ever gone through a fog, you have passed through a cloud, too. A fog is just a cloud that is near the earth's surface. Sometimes it is so thick that you cannot see through it. You know that fog feels wet. It is made of very tiny drops of water floating in the air.

Do you know how this water gets into the air? If you put some water in an open dish or pan, the water soon disappears. Wet clothes become dry when they are hung on a line. After a rain, puddles disappear. And the ground becomes dry again.

When water disappears into the air, we say that the water evaporates. The water changes from a liquid to a gas. This gas is called water vapor. You cannot see water vapor. It mixes with the other gases in the air.

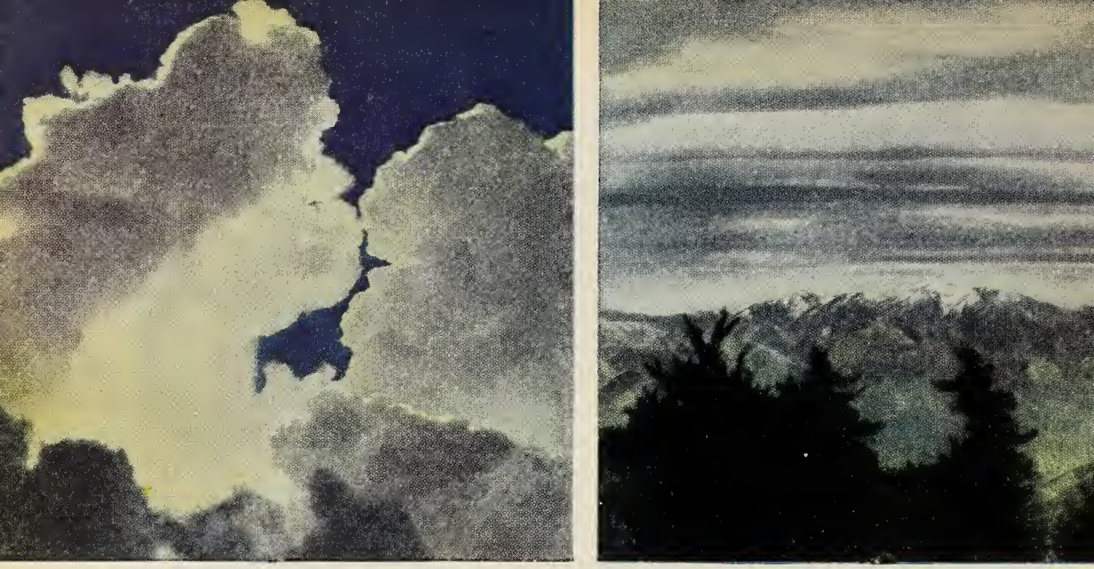
Water is always going into the air from oceans, lakes, rivers, and streams. It evaporates from wet soil, wet grass, and wet trees, too. The warmer the water is, the faster it evaporates. And the warmer the air is, the more water vapor it will hold. When you want to dry your wet clothes quickly, you hang them in the hot sunshine or near a heater. The water soon disappears into the air.

The water vapor in the air can change back to a liquid. Suppose you put some chipped ice in a dry metal cup. Then let the cup stand in a warm room. Drops of water soon gather on the outside of the cup. The ice makes the cup cold. Then the cold cup cools the air that touches it. This air has water vapor in it. But cool air cannot hold so much water vapor as warm air can. So some of the water vapor comes out of the air and changes to liquid water.

When water vapor changes to water, we say that the water vapor condenses. You have seen this happen many times. The little white cloud near the spout of a teakettle is made of tiny drops of condensed steam. If you hold a cold plate near the spout of the teakettle, drops of water will gather on the plate. As you know, steam is just water vapor that comes from boiling water. When steam is cooled enough, it changes back to liquid water. When this happens, a little cloud is made.

On a cold day you can see your "breath." The warm air that you breathe out is full of water vapor. When this warm, moist air strikes the cold air outside your body, it is cooled. Then it cannot hold so much water vapor. As some of the water vapor condenses, it makes the little cloud that you see. If you blow your breath against a cold windowpane, water vapor in your breath will condense on the cold glass.

Now do you see how a cloud is made in the sky? There is always some water vapor in the air. When the air is warm, it can hold much water vapor. But if the air is cooled, it cannot hold so much. Then some of the water vapor condenses, and tiny drops of water are formed. They are so small and so light that they float in the air. A cloud is made of many, many of these tiny drops floating along together.



After you have read this page, tell what kinds of clouds are shown in these pictures.

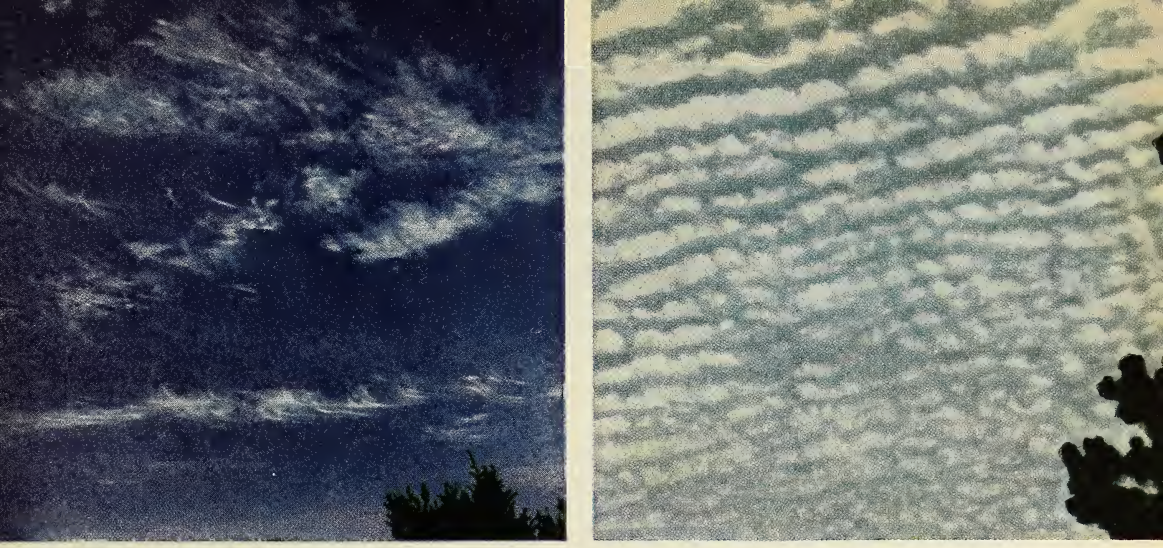
When the air can hold all the water vapor that is in it, the sky is clear. Water vapor does not condense, and no clouds are formed. But when the air cannot hold all of its water vapor, some of the water vapor condenses. Clouds form, and the sky becomes cloudy.

If the temperature of the air changes, the condition of the sky may change, too. Water vapor will condense into clouds if the air is cooled enough. So a day that starts out clear may become cloudy. Or clouds will evaporate into water vapor if the air is warmed enough. Then a cloudy day may become clear.

You have often watched clouds as they move by. Sometimes they race along, but other times they hardly seem to move. The harder the wind blows in the sky, the faster the clouds go. The wind can make a cloudy sky clear by driving away the clouds. Or it can make a clear sky cloudy by bringing clouds from somewhere else.

As you watch the clouds, you can easily learn to tell the three main kinds. One kind of cloud looks like a white puff of cotton or wool. You often see this kind on a hot summer day. Scientists call this kind a *cumulus* cloud. Cumulus means heaped up or piled up. The top of a cumulus cloud may be over a mile above the earth, while the bottom is within a few hundred feet of the earth.

Another kind of cloud that you have often seen is smooth and gray. It usually covers the whole sky. Then you cannot see the sun or the moon and the stars. This cloud may be from 400 feet to over 2000 feet above the earth. Scientists call this kind a *stratus*



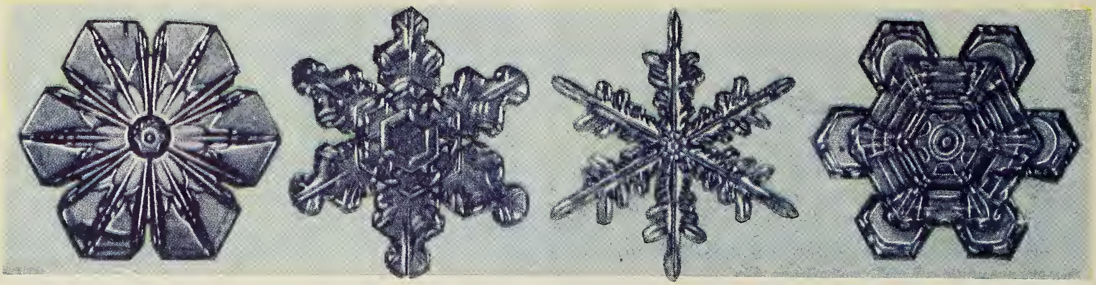
These are kinds of cirrus clouds. The picture on the right shows a mackerel sky.

cloud. Stratus means layer, which is a good name for this cloud.

The third kind of cloud is the highest in the sky. It may be from six to nine miles above the earth. At this height, the air is so cold that water vapor condenses into tiny bits of ice. So this cloud is made of ice instead of water. Scientists call it a *cirrus* cloud. Cirrus means curl or tuft. Sometimes this cloud looks like little curls or tufts. At other times, it looks like threads or feathers. A "mackerel" sky has a kind of cirrus cloud. The clouds make a pattern that looks like the pattern on a mackerel's back.

---

1. *Explain how water gets into the air.*
2. *How is a cloud formed?*
3. *Why does a fog disappear when the sun comes out?*
4. *Do you believe each of these statements? Give your reasons.*
    - *a) On a clear day, there is no water vapor in the air.*
    - *b) On a cloudy day, you can see much water vapor in the air.*
    - *c) Water vapor changes to water when air is cooled.*
5. *Ice sometimes forms on an airplane as it comes down from high above the earth. Why do you think that this happens?*
6. *On a summer day, a pipe carrying cold water had drops of water on the outside. If there was no leak in the pipe, how did the drops of water get there?*



How does water come out of the air?

SOMETIMES THE SKY is clear, without a cloud in sight. Then in a few hours big clouds may appear. Soon the air is full of raindrops or snowflakes. Perhaps sleet or hail comes down, too. Rain, snow, sleet, and hail are all made by water coming out of the air. But how does water come out of the air in these ways? You can use what you have already learned about clouds to help answer this question.

When air that contains much water vapor is cooled, some of the vapor condenses and comes out of the air. At first, only tiny drops of water are formed. They float in the air and make clouds. When only a little water vapor condenses, the clouds are thin. But when much water vapor condenses, the clouds are thicker.

If the air in the clouds gets colder, more water vapor condenses. The tiny drops of water join together to make larger and larger drops. At last, they are too big and too heavy to stay up in the air. They fall to the earth as raindrops. Then we have rain.

As raindrops fall from the clouds, they sometimes pass through air where the temperature is below freezing. When the raindrops freeze, we have sleet. Sleet is just frozen rain, or tiny bits of ice mixed with rain.

If there are strong currents of air moving up and down, the raindrops may be carried up and down many times before they reach the earth. They may pass from air that is above freezing to air that is below freezing. Each time they go from warmer air to colder air, a layer of ice may be added. In this way, hail is formed. Hailstones sometimes get as big as marbles or even hen's eggs. They may break windows and ruin crops.

Sometimes air must be cooled below freezing before the water vapor will come out. When this happens, the water vapor changes to a solid instead of a liquid. It forms snowflakes, and then we have snow.

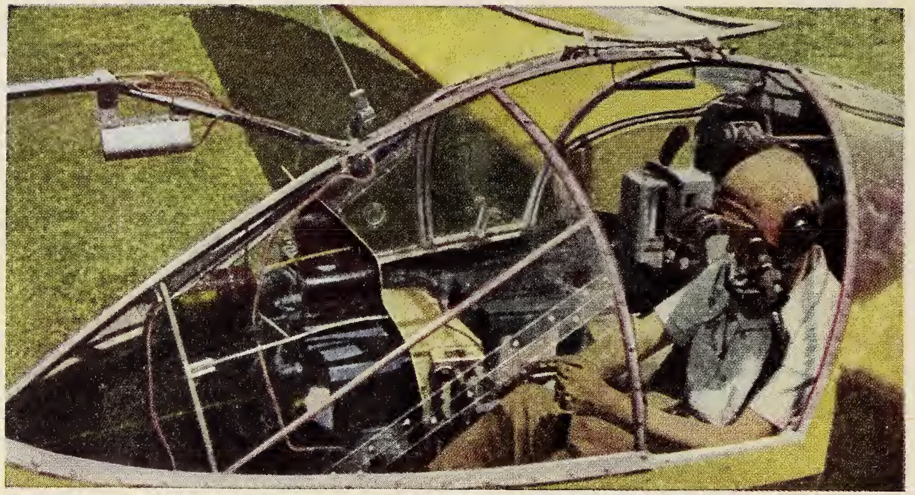
You can find many beautiful patterns in snowflakes. The next time that it snows, let some of the flakes fall on your coat sleeve. Then look at them with a magnifying glass. You will see that they usually have six sides or points. Each one seems to be different. You will not find two snowflakes that are exactly alike. The picture on page 48 shows several snowflakes as they look under a microscope.

On a summer morning, you may find grass and other things outdoors wet with dew. In the spring or the autumn, when the weather is cooler, these things may be covered with white frost. Where do you think the dew and the frost come from? People used to think that they came from the ground. But scientists know that dew and frost really come from the water vapor in the air.

Suppose that it is a warm, clear summer day. Water is evaporating into the air. After the sun goes down, the soil, the plants, and the buildings become cooler. The air that touches these cool things becomes cooler, too. This cool air cannot hold all the water vapor that it took up during the day. So some of the water vapor condenses. Drops of water form on the soil, the plants, and the buildings. These drops of water are called dew.

But in the spring or the autumn, the temperature of the air sometimes falls below freezing at night. Then the water vapor in the air changes directly into a solid, just as it does when snow is formed. This solid is called frost. Some people think that frost is just frozen dew, but that is not correct. The water vapor in the air changes directly into frost without first becoming water.

1. *What change must take place in the air before water vapor will condense?*
2. *How would the weather be different if water did not evaporate?*
3. *Tell how you could use a kettle of boiling water and a cold plate to explain how rain is made.*
4. *Do snow and sleet both come out of the air in the same way? Explain your answer.*
5. *Do you believe each of these statements? Give your reasons.*
    - *a) Without the help of gravity, we would not have rainy weather.*
    - *b) Water that is now in a puddle may sometime fall from the sky.*
    - *c) Hailstones are balls of ice.*
    - *d) Dew sometimes freezes and forms frost.*
    - *e) Frost and dew fall from the sky, just as rain and snow do.*



Scientists are trying to find out more about thunderstorms. This glider was towed up into a stormy sky and cut loose. The pilot and his instruments came down through the storm and recorded what was happening inside the storm.

What does the weatherman do?

YOU HAVE PROBABLY heard jokes about the weatherman, and you may have seen funny pictures of him. People sometimes ask, "Why doesn't the weatherman shut off this rain?" Or they say, "I wish the weatherman would turn on some more heat."

Of course, no one has ever been able to control the weather and give us just the kind we want. But people still blame the weatherman for bad weather. And they make fun of him when the weather report is not correct. Who is the weatherman? What does he do about the weather?

If you want to find out what the weather is going to be, you probably look in a newspaper for the weather report. Or you listen to the radio to get the weather report. This report is made by the United States Weather Bureau. When we talk about the weatherman, we really mean the Weather Bureau. Or we mean one of the scientists who work for it.

The main office of the Weather Bureau is in Washington, D.C. It has district offices in several big cities, such as Boston, Chicago, New Orleans, Kansas City, Denver, and San Francisco. There are also more than 300 weather stations in different parts of our country. The work of the Weather Bureau is to *forecast* the weather. Forecast means tell what is coming. The weather report is called the *weather forecast.* It tells what kind of weather is probably coming.

Scientists in the offices and stations of the Weather Bureau do the work of forecasting the weather. These scientists study the weather very carefully and watch its changes. They study the clouds and the winds. And they find out what kind of weather the different clouds and winds are likely to bring.

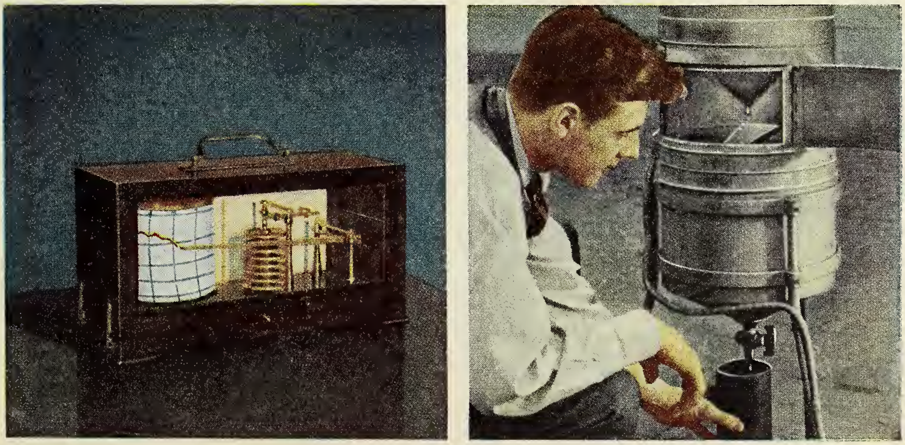
Like all scientists, the weathermen use many instruments to help them with their work. They must find out what is happening to the air in every part of our country. Every weather station has a thermometer that measures the temperature very accurately. This thermometer also makes a record of the temperature as it changes.

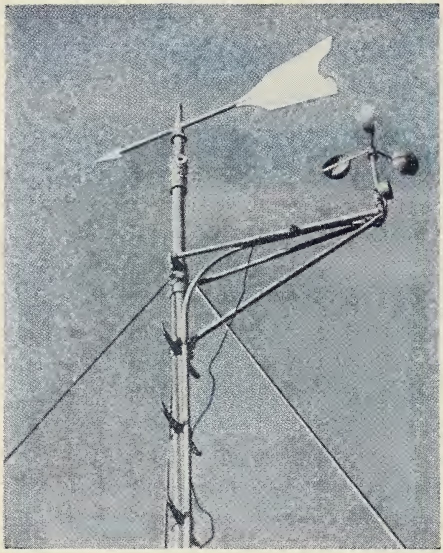
The weather scientists also have an instrument that measures the pressure of the air. This instrument is called a *barometer.* One kind of barometer makes a record of the pressure of the air as it changes during the day.

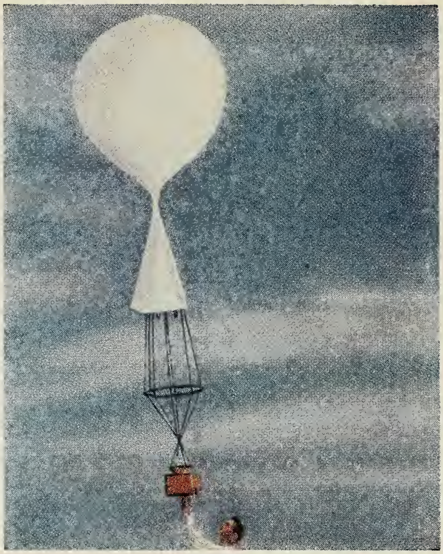
Each weather station has an instrument to tell how much water vapor there is in the air. Another instrument shows the amount of rain that falls. This instrument is called a *rain gauge.* It is a metal can about eight inches across and twenty inches high. The rain gauge is set in an open place where the rain can fall into it. Every day when rain falls, the weatherman measures the water with a ruler to find out how deep it is.

The scientists of the Weather Bureau also want to know the direction and speed of the wind. A weather vane shows which way the wind is

The picture on the left shows a barometer that makes a record of the pressure of the air as it changes. The other picture shows a rain gauge that is connected to an instrument in the Weather Bureau. When a certain amount of rain has fallen, it is recorded on the instrument.







blowing. Another instrument measures how fast the wind is blowing. It is spun around by the wind. The faster the wind is blowing, the faster it spins. The picture on the left on this page shows one of these instruments.

Some weather stations send up small balloons to find out which way and how fast the wind is blowing high above the earth. Other weather stations send up larger balloons with radio sets fastened to them. As this balloon goes up, the radio set sends out reports of the weather in the upper air. When the balloon gets high above the earth, it bursts. Then a parachute carries the radio set safely back to earth. The radio set has a tag on it, asking anyone who finds it to send it back to the Weather Bureau.

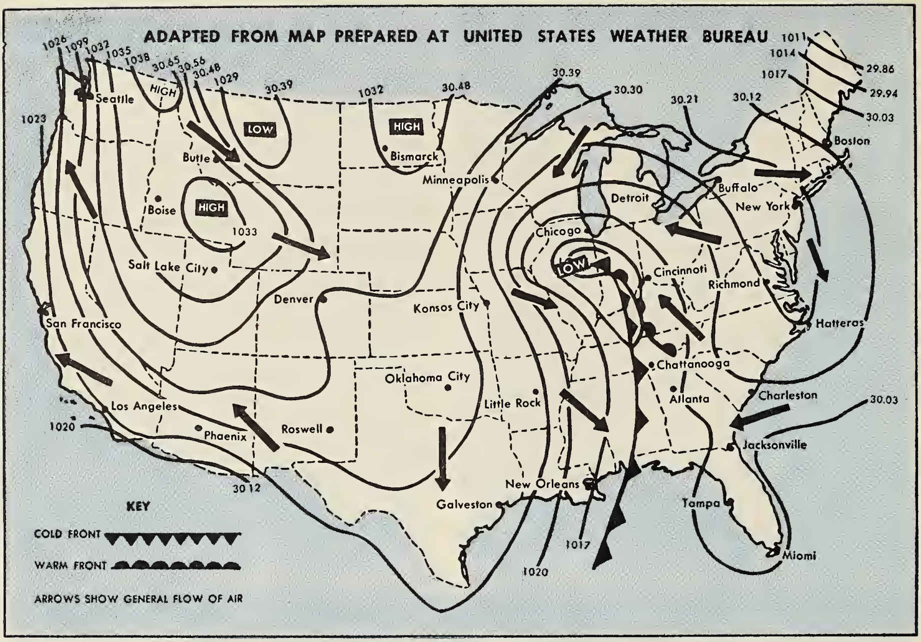
For many years, scientists of the Weather Bureau have kept records of weather as it changes from day to day. The records show the temperature, the winds, the condition of the sky, and the amount of water coming out of the air. They give the hottest day and the coldest day for many years gone by. They tell how much rain or snow usually falls during each month of the year. And they also show how much sunshine there usually is in every part of our country. By studying these records, scientists have learned a great deal about the weather.

Most people want to know what the weather is going to be, not just what the weather has been. So the scientists of the Weather Bureau have worked out a way to forecast the weather. Every day, each weather station makes a report of the weather at the place where the station is. The report gives the highest and the lowest temperatures of the day before, the direction and the speed of the wind, the condition of the sky, and the amount of water coming out of the air. It also gives the pressure of the air.

This report is sent to the cities where weather forecasts are made. In these cities, scientists study the reports from the weather stations. Then the scientists make a *weather map*. On this map, they put the things that they learned from the weather reports. When the map is finished, it shows what the weather is in all parts of our country.

The picture on page 54 shows a weather map. Perhaps you have seen maps like this in newspapers. It may look like only a jumble of lines to you. But this map is really much simpler than the maps that weather scientists use. Later in your study of science, you will probably learn more about weather maps. Then you will find out how the lines are drawn and what they mean.

These boys have found a balloon and radio from the Weather Bureau. They are looking to see where to send the radio.



When a scientist looks at a weather map, he sees a picture of what is happening to the weather all over our country. He can read this map just as you can read an ordinary map. The weather map shows him where there are large masses of cold air and warm air. It shows him where the air is moist or dry. He can see in which direction the masses of air are moving. He can also tell about how fast they are moving.

All these things show the scientist what the weather will probably be in different places. So he can make a weather forecast from the weather map. As soon as this forecast is made, it is sent to newspapers and radio stations. It is also sent by telephone and telegraph to other cities.

Is the weather forecast usually correct? Here is a good way to find out. Compare the weather forecast each day with the weather you actually have the next day. Do this for several weeks. How many times was the forecast correct? How many was it not?

You must remember that the weather forecast is made for a large district. So it may not tell the exact kind of weather that you will have near your home. Suppose the forecast is "showers." It may rain hard a few miles away but never even sprinkle near where you live. Yet you should not say that the forecast is wrong.

Of course, the weather forecast is not always correct. Sometimes a storm comes up without much warning. Or changes in the air take place so fast that the Weather Bureau cannot forecast them. But you will find that the weather forecast is correct much more often than it is not correct.

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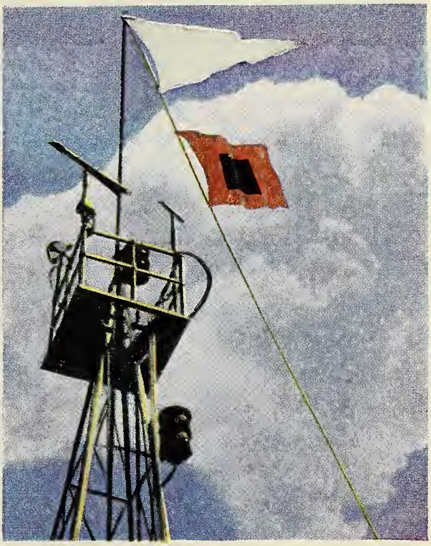
1. *What things do scientists watch so that they can forecast the weather?*
2. *Name some instruments that scientists use to study the weather.*
3. *How do weather stations help scientists forecast the weather?*
4. *When a scientist studies a weather map, what are some things he can find out?*
5. *Why is the weather forecast not always correct for the place where you live?*

How do weather forecasts help us?

EVERY YEAR, the work of the Weather Bureau saves hundreds of lives and millions of dollars. Many people may change their plans when they get the weather forecast. Here are some things that happened one day because the weather forecast said, "Much colder with very strong north wind. Probably very heavy snow within twenty-four hours."

People put on warmer clothes before they left home to go to work or to school. Some of them put storm windows and storm doors on their homes. They started fires in their furnaces. Fuel dealers had a rush of orders from people who needed more coal or oil to heat their homes. Farmers made sure that their cows, sheep, pigs, and chickens were in a safe place. Shippers packed fruits and vegetables so that they would not freeze on the way to market in trains and trucks.



These storm signals warn people that a storm is coming from the northwest.

Steamship companies warned their boats to get ready for a storm or to hurry into a safe harbor. Air lines

Air-line pilots study the weather map before taking off.

sent radio messages to all their airplanes. Many planes were not allowed to start on long trips. Telephone, telegraph, and electric companies had men ready to repair damaged wires. Highway departments got their snowplows out so that they could clear the snow off the roads as soon as it fell.

The weather forecast was correct. The temperature went down below freezing. A strong north wind blew, and it snowed very hard. The storm did some damage and made some people uncomfortable. But most people were ready for it, because the Weather Bureau had warned them in time to get ready for it.

Farmers are always watching the weather forecasts for warnings of bad weather. At harvest time, if rain is forecast, they hurry to get their hay and grain into barns or stacks. Then the rain cannot spoil the crops. In the spring, the farmers watch for a forecast of dry weather so that they can plow their fields and plant their crops.

Fruit growers also watch the weather forecasts closely. If a heavy frost comes when fruit trees are in blossom, the blossoms may be frozen. Then there will be no fruit. Sometimes, when frost is forecast, fruit growers build fires in their orchards to warm the air and keep the blossoms from freezing. Vegetable growers wait until the danger of frost is past. Then they plant their crops.

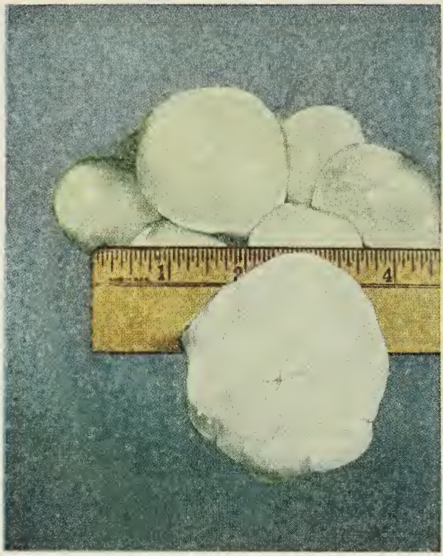
Shippers of fruits and vegetables need the weather reports, too. In cold weather, the forecasts help them decide how to pack this food to keep it from freezing. In warm weather, the forecasts help them decide what to do to keep the fruits and vegetables from spoiling.

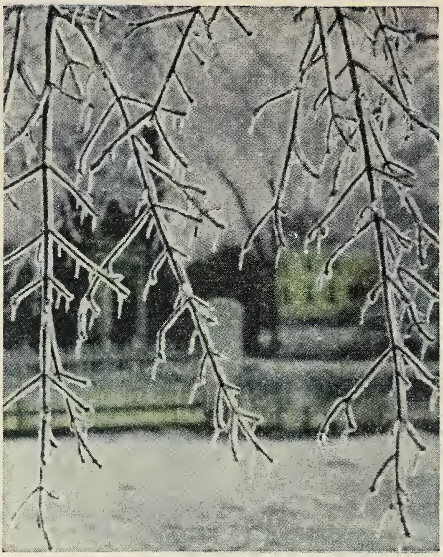
To fly their airplanes safely, pilots make much use of weather reports. They need to know what the weather is high above the earth. Up there, the air is colder than it is near the ground. The direction and the speed of the wind are usually different, too. Pilots also must know when to expect fogs, storms, and ice. Most air lines get weather reports from their own scientists as well as from the Weather Bureau.

You can see how weather forecasts help us in many ways. They warn us of sudden heat or cold and of storms, frosts, and floods. They tell us to watch for forest fires if the weather is dry. They also tell us when to expect the kind of weather we want. If we know what the weather is going to be, we can make our plans to fit the weather.

1. *How do weather forecasts help us? Give as many different ways as you can.*
2. *How do scientists help us by studying the weather?*
3. *Why do airplane pilots need special weather reports?*

When the weather is cold, orange growers warm the air in the groves with heaters.





QUESTIONS TO ANSWER

1. What changes in the air change the weather?

2. Where does dew go when it disappears?

3. Why do fogs come more often at night than in the daytime?

4. What will happen if warm, moist air is pushed up into much colder air?

5. How does gravity help make the weather change?

6. Electric companies watch the weather reports to find out if the sky will be cloudy or clear the next day. Why do you think they do this?

7. Figure out how much the air in your schoolroom weighs.

8. Explain why drops of water form on the outside of a pitcher of ice water when it stands in a warm room. Where do the drops of water come from? Explain your answer.

9. Look at the pictures on these two pages. What does each one show? How did each one come about?

THINGS TO DO

1. Cut out a weather forecast from a newspaper and bring it to class. Make a list of all the things you have learned in this unit that help you understand the forecast. Explain how they help you understand the forecast.

2. Make a wind vane and set it up where you can see it easily. Keep a record of the direction of the wind each day for a month. From what direction does the wind usually blow where you live?

3. Set an open can in a place where it is not sheltered by trees or buildings. Use this can as a rain gauge. Each time it rains, measure the rain in the can with a ruler. Find out how many inches of rain fall in a month where you live.

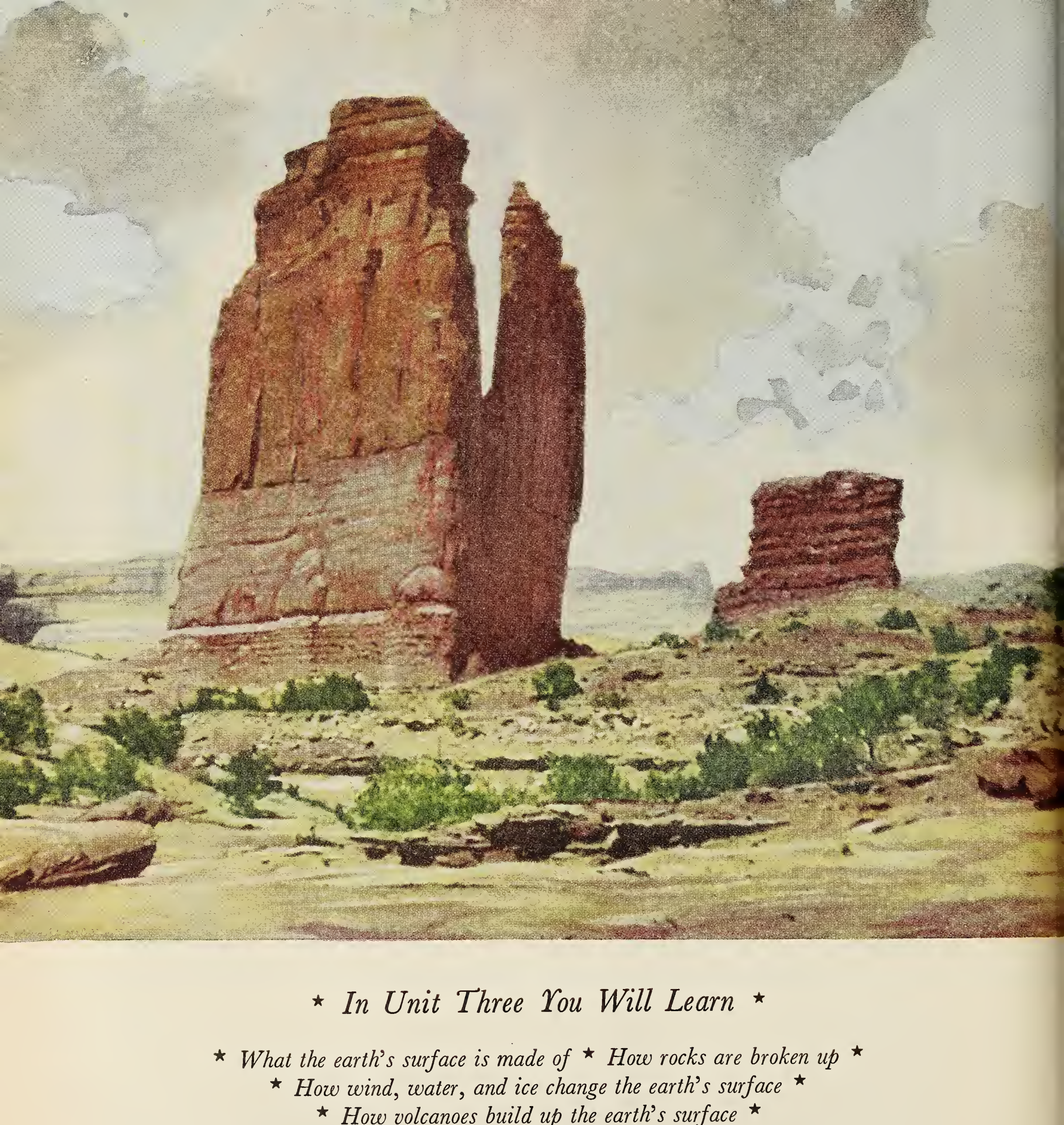
4. Read more about the different kinds of instruments used by the Weather Bureau. Find out how they are used.

5. Make a scrapbook of newspaper stories about unusual weather.

6. Get a weather map from the Weather Bureau. Find out what some of the marks on it mean.

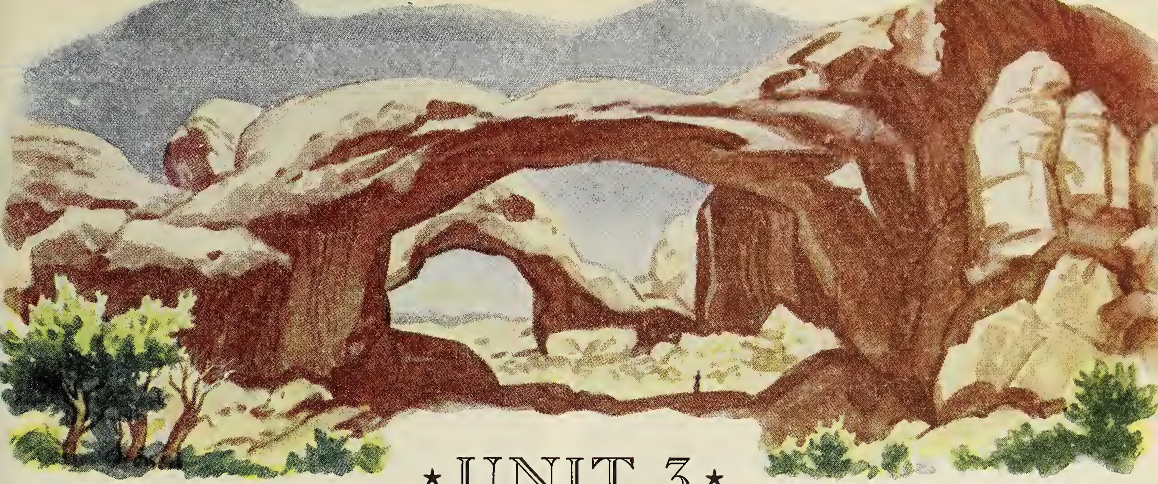
7. Make a list of sayings about the weather. Find out whether they are true or false.

8. If there is a weather station near your home, try to visit it.



★ *In Unit Three You Will Learn* ★

★ *What the earth's surface is made of* ★ *How rocks are broken up* ★
★ *How wind, water, and ice change the earth's surface* ★
★ *How volcanoes build up the earth's surface* ★
★ *How mountains are made* ★ *How we can conserve the soil* ★



⋆ UNIT 3 ⋆

How Is the Earth's Surface Changed?

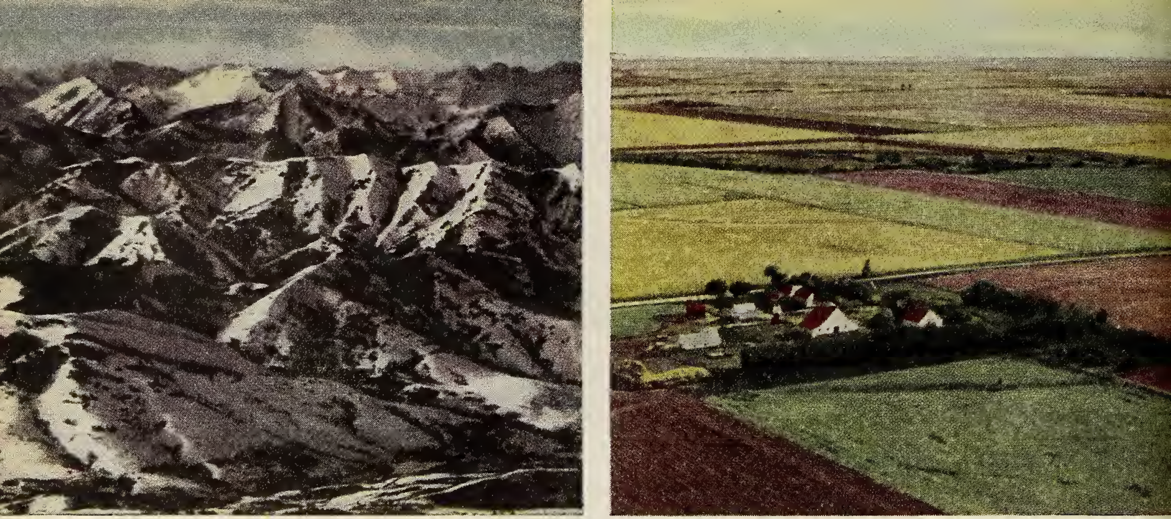
WHAT DOES the land look like around the place where you live? Is it flat or hilly? Are there mountains and valleys? Can you find rivers, lakes, or swamps nearby? Do the rivers run swiftly or slowly? What kinds of rocks can you find? Do big rocks stick up out of the ground? Or are stones just scattered here and there?

But do you think that the land around you always looked just as it does today? Talk with people who have lived near your home for a long time. They can probably tell you about some changes in the earth's surface near where you live. And even in your own lifetime you may have seen some changes.

The banks of streams cave in or wash away. Wind blows dry soil and piles it in heaps. Rivers and creeks become shallower and narrower. Sometimes a stream changes its path, or a lake fills up with soil. Maybe you have watched some of these changes take place. Many other changes in the earth's surface take a long, long time.

Suppose that you could see the land around you as it was a hundred thousand years ago and then several million years ago. Would it look the same each time? Of course, you can only guess what the answer to this question would be. But scientists do not have to guess. For many years, they have studied the history of the earth. They know that many changes in the earth's surface have already taken place. And they also know that some changes are still going on in many parts of the earth.

A scientist might tell you that the place where you live was once at the bottom of the ocean. Or he might say that at another time it was covered



Some parts of our country have high mountains. Other parts are flat plains.

with ice hundreds of feet thick. At some other time, it may have been up on a mountain or down on a plain. Scientists know that different parts of our country have changed in different ways. As you study this unit, you will find out what some of the changes were. You will also learn how changes in the earth's surface are made and what changes are still going on.

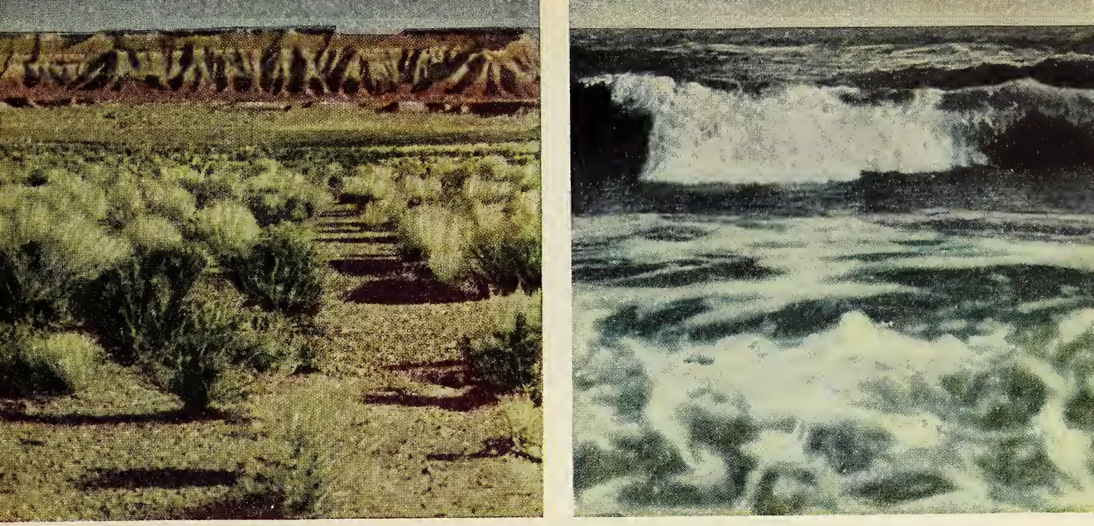
What is the earth's surface made of?

IMAGINE THAT you are in an airplane high above the earth. Looking down, you can get a bird's-eye view of miles and miles of the earth's surface. Pretend that you are up so high that you can see from one side of our country to the other.

Along the east and west sides of our country, you see huge bodies of water. These are the Atlantic and Pacific oceans. You see many smaller bodies of water, too. These are lakes. The largest ones that you see are the five Great Lakes. If you look more closely, you can find hundreds of smaller lakes.

You also see long streams of water flowing across the land. These are rivers. Some of them, like the Mississippi, Missouri, and Ohio rivers, are hundreds of miles long. If you were nearer the earth, you could see many smaller streams creeping across fields or rushing down the mountainsides. These streams are creeks and brooks.

The big rivers and the little streams are all alike in one way. They are all traveling downhill. As you know, the force of gravity makes them do this. Some hurry along. Others flow slowly. But they all run downhill and pour their water into low places on the



Deserts and oceans cover large parts of the earth's surface.

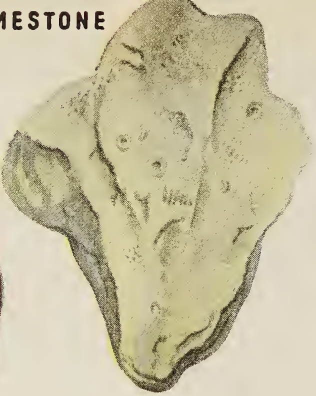
earth's surface. More than three fourths of the earth's surface is covered with water. Less than one fourth is land.

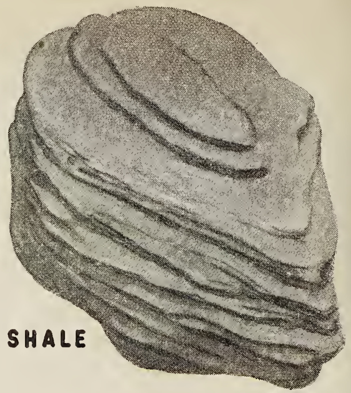
Now look more closely at the land. Here and there you see big flat stretches. Some of them are covered with forests. Some are prairies covered with grass. Others are deserts with very little growing on them. In other places, the land is not flat. You see miles of hills and valleys. Higher than the hills are the rough, jagged mountains. Some of the mountain peaks are almost three miles high! Look at the pictures on these two pages. They show how different the earth's surface is in different places.

The land is made of either rock or soil. In high mountains and some other places, you can see bare rock. In most other places, you find soil. But if you dig down far enough into the soil, you will always come to rock. The kinds of rocks under the soil mean much to a scientist. By studying the rocks, he can discover how that part of the earth's surface has changed.

In hilly country, places must often be cut through rock so that highways and railroads can be built. On the sides of these cuts, you may see different layers of rock. You can easily tell one layer of rock from another. The colors of the layers are different. So are the sizes of the tiny pieces that make up the rocks. Look at the picture on the left on this page. You can see the layers of rock.

Scientists have discovered different kinds of rocks. They have also found out why some kinds are in layers. One kind of rock is called *sandstone*. It is made of tiny bits of sand pressed together so hard that they make stone. The sand is carried to the ocean by rivers. It settles from the water and sinks to the bottom of the ocean. You





will learn more about this later in the unit.

This goes on for thousands or even millions of years. As more and more sand sinks to the bottom of the ocean, the sand becomes harder and heavier. The top layers of sand and the water over them press with great force on the lower layers. The bits of sand in the lower layers are pressed together so hard that they make sandstone.

Another kind of rock is also made under water. It is called *limestone*. The bones of fishes and the shells of sea animals sink to the bottom of the ocean. You can often find the shells in a piece of limestone. Layer after layer of bones and shells settles on the bottom of the ocean. The great weight of the top layers and the weight of the water press the lower layers into stone. Of course, this takes many, many years.

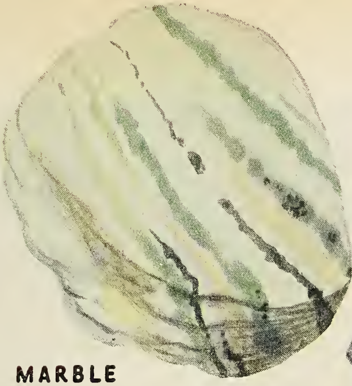
A third kind of rock that is made under water is called *shale*. It is made of mud that is carried to the ocean by the rivers which flow into it. The mud sinks to the bottom. Like sandstone and limestone, shale is formed after many years of great pressure.

Scientists have a name for the kinds of rocks that are made under water. They are all called *sedimentary* rocks, because they are made from *sediment*, or solid pieces that settle from water. Sedimentary rocks are usually found in layers. You can see the layers in the pictures on pages 63 and 73.

But why do we find sedimentary rocks hundreds or even thousands of feet above the oceans and many miles away from it? Scientists wondered about this for a long time. They knew that the rocks must have been made under water. So they decided that there was only one way to explain this strange thing.

After the rocks were formed, some great force must have pushed them up. Then the water that had covered them ran down to lower places on the earth's surface. And the rocks were left as a layer on dry land. Thousands or millions of years later the land sank. Once more, the layer of rock was covered with water. Sand, mud, or bones and shells settled on the

GRANITE



MARBLE

SLATE

rock. At last, a new layer of rock was formed on top of the old layer. Again the land was pushed up, and the water ran off.

All this happened over and over again. Each time, a new layer of rock was added. It was often a different kind of rock from the layer underneath. First, there might be a layer of limestone. On top of this, a layer of shale would form. Then there might be a layer of sandstone. That is why different kinds of sedimentary rocks are found in the same place. But no matter what kinds you find, you know that the place must have been under water when the rocks were made.

Scientists find other kinds of rocks that were made from sedimentary rocks. One kind is called *marble*. It was made from limestone that was heated and then crushed with great force. For this to have happened, the limestone must have been covered with heavy layers of rock.

Rocks made from sedimentary rocks in this way have a special name. Scientists call them *metamorphic* rocks. Metamorphic means changed. The sedimentary rocks were changed by great heat and pressure. You can probably find another kind of metamorphic rock in your schoolroom. Blackboards are often made of *slate*. Slate is a rock formed from shale that was heated and crushed.

In many places on the earth's surface, there are huge masses of other kinds of rocks that were also formed by heat. These rocks are mixtures of minerals that have many different colors. Scientists can explain how these rocks were made, too.

Far below the earth's surface, it was very hot. The great heat melted solid rock a mile or deeper in the earth. Then pressure forced the hot, liquid rock upward. Sometimes it flowed between layers of sedimentary rock. At other times, it spread out over the earth's surface. Then it began to cool slowly. After a long time, it changed back to solid rock.

The rocks made from liquid rock in this way are called *igneous* rocks. Igneous means formed by fire. There are many kinds of igneous rocks. The kind that you have probably seen is called *granite*. This is a very hard rock. It can be polished until it is smooth and shiny like glass. And it may be red, green, gray, or blue.

Now you can understand where the different kinds of rocks came from. You can also see how a scientist uses the rocks to learn about changes in the earth's surface. When he finds certain kinds of rocks in a place, he knows what must have happened there long, long ago.

In many places, the rocks are covered with soil. You can easily find out what soil is made of. Put a handful of soil in a tall glass jar or bottle. Fill the jar or bottle with water. Stir the soil and water thoroughly. Then shake them until the soil is completely mixed with the water. Let the jar or bottle stand where it will not be disturbed.

Then look at the soil the next day. What happened? As the soil settled, the heaviest materials sank to the bottom first. Next came the lighter materials. Some material still floated in the water. You can probably see three kinds of materials. On the bottom is sand. If there are several layers of sand, the bottom layer will have the biggest pieces. Above the sand is clay. Decayed plant and animal material floats in the water.

Where do the materials in soil come from? Of course, the decayed material comes from the bodies of plants and animals. Look at the sand with a magnifying glass. You can see that it is made from bits of rock. The clay is also made from rock that was ground to powder. So both the sand and the clay in soil tell a scientist about changes that must have taken place in the earth's surface.

Long, long ago, the earth was just a ball of rock. It had no soil. But scientists know that some of the materials in soil were made from rock. Somehow the rock must have been broken into tiny bits and then spread over the earth's surface. For this to have happened, great changes in the earth's surface must have taken place. As you study this unit, you will find out how these changes were made.

1. *Which one of these statements is true? Which one is not?*
    a) Most of the earth's surface is dry land.
    b) The solid part of the earth's surface is either soil or rock.
2. *Name three kinds of rocks made under water and tell how each one was formed.*
3. *Name three kinds of rocks made by heat and tell how each one was formed.*
4. *Do all the materials in soil come from rock? Explain your answer.*
5. *What have scientists learned by studying rocks and soil?*

The piles of rocks at the foot of this cliff show that it is slowly being broken up.

How are rocks broken up?

Did you ever say that something was "hard as rock"? You meant that it was very, very hard. Most kinds of rock are very hard. That is why people for hundreds of years have used rocks in building. Streets, sidewalks, bridges, churches, and many other things have all been made from rock.

Of course, huge chunks of rock must first be broken into pieces that are small enough to use. To do this quickly, great force is needed. Powerful drills bore holes in the rock. Dynamite is put in the holes. When it explodes, the rock breaks into many pieces.

On the earth's surface, many forces are always at work, breaking up rocks and wearing them away. Big forces may act quickly, almost like an explosion. Smaller forces take a long, long time.

Changes in the weather break up rocks. You can see one way that this happens by doing an experiment. Get a thick drinking glass or a thick glass bottle. Fill it with cold water. Let it stand until the glass feels cold. Then pour out the cold water. Now quickly pour very hot water into the glass. Usually the glass will crack. The same thing will happen if you pour cold water into a hot glass. Try it and see.

How do you think this rock became so cracked? What will happen sometime?

Now let us find out why the glass cracked. You know that heating makes things expand, or get larger. You also know that cooling makes them contract, or get smaller. Hot water made the cold glass expand. The glass next to the hot water expanded faster than the rest of the glass. This made the glass crack. If you pour cold water into a hot glass, the same thing will happen. The glass next to the cold water will contract faster than the rest of the glass.

When the sun shines on bare rocks, they get very hot. Maybe you have sat on one that was too hot for comfort. The inside of the rock is much cooler than the outside. The outside expands faster than the inside. Then the rock cracks. At night, rocks become cooler. The outside cools faster than the inside. As the outside contracts, more cracks are formed. This happens over and over again. The cracks get bigger and bigger. At last, pieces of rock break off.

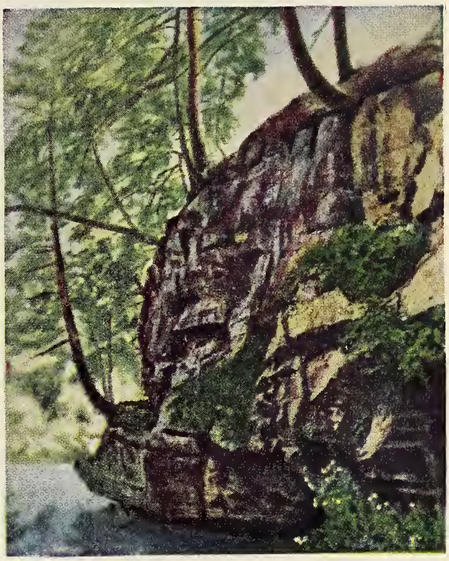
Here is another way that a change in the weather breaks up rocks. An experiment will show you what happens. Get a glass bottle or jar that has a screw top. Fill it as full of water as you can. Screw the top on tightly. If it is freezing weather, set the bottle or jar of water outdoors. Or you can put it in the part of an electric refrigerator that makes ice cubes. Leave the bottle outdoors or in the refrigerator until the next day.

Look at the bottle or jar the next morning. What happened? Water and some other liquids are different from most things. Water expands when it freezes. The water in the bottle expanded when it froze. As it expanded, it pushed with great force against the glass. At last, the glass cracked. Freezing water expands with so much force that it can even break iron pipes. You may have heard about water pipes bursting in buildings because the water in the pipes froze and expanded.

Now you can understand how freezing water can break up rocks. Rain falls on rocks, or snow melts on them. The water runs down into cracks in the rocks. If the weather is cold enough, the water freezes. As it expands, the cracks in the rocks get bigger. The force of freezing water breaks the rocks into smaller and smaller pieces. As the years go by, huge mountains of rock are broken down in this way.

Plants can break up rocks, too. This is how they do it. The wind carries the seeds of trees and other plants. Some of the seeds fall on rocky places in the mountains or on rocks in fields and valleys. Perhaps there is some soil on the rock. The seeds may fall on this soil. Rain or melting snow wets the soil. The seeds sprout and begin to grow into plants. The plants send out tiny roots.

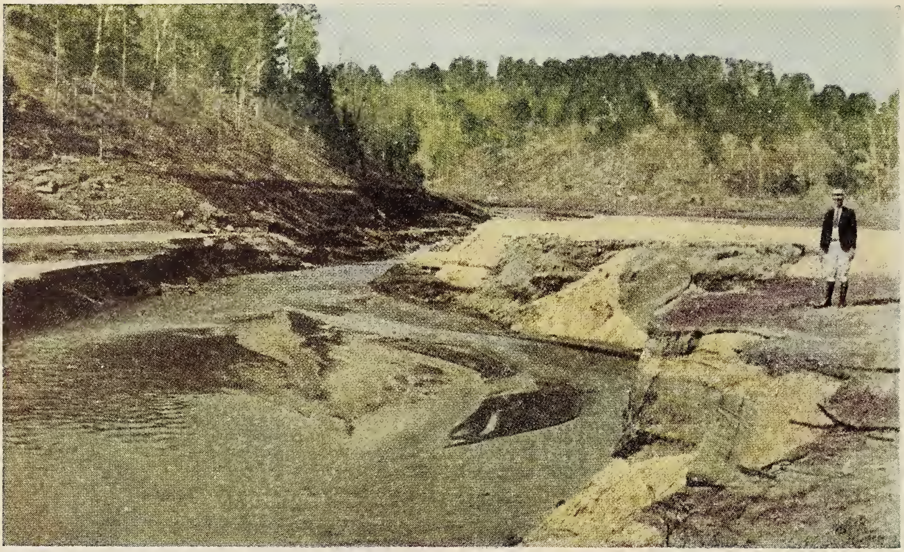
These tiny roots can squeeze into the smallest cracks. Some of them force their way into cracks in the rock. As the years go on, the roots grow bigger and bigger. And as they grow, they have enough force to split the rock into pieces. Perhaps you have seen sidewalks broken by the roots of trees. Sometimes a sewer pipe underground is broken open by tree roots. Tiny roots get into a little crack in the pipe. As the roots grow larger, they break the pipe.



What do you think these trees can do to the rocky cliff they are growing in?

Now you know three ways in which rocks are broken up. Heating and cooling crack the rocks. Freezing water makes the cracks bigger. And plant roots do the same thing. As you study this unit, you will learn some other ways in which rocks are broken up and worn away. Then you can understand how rocks in the earth's surface were changed into soil.

1. *Explain how heating and cooling break up rocks.*
2. *How does freezing weather help break up rocks?*
3. *Tell how a tiny seed can split a huge rock into pieces.*
4. *Look again at the picture on page 67. Explain how this huge mountain of rock is slowly being broken down.*



The water is carrying away the soil from the banks of the stream. Where do you think this soil goes?

How does water change the earth's surface?

EVERY DAY IS moving day for water, and its work does not stop at night. In every river, creek, and brook, water is running downhill to lower places. It is pulled down by the force of gravity. You know that moving water can make other things move with it. If you throw a stick into a river, the moving water carries the stick along. As the water in streams flows on its way, it takes part of the earth's surface with it. So water is one of the giant movers that change the land.

You can see for yourself how this change takes place. Go outdoors some day after there has been a heavy rain or when the snow is melting. Notice what happens to the water. Some of it soaks into the ground, and some evaporates. But much of it flows off the land in streams.

Suppose you follow a stream from its very beginning. At first, the stream is small. As it flows along, it is joined by other small streams. Soon it makes a little brook. As the water travels on down, other little brooks join it. The brook becomes a good-sized creek that flows through a little valley.

By this time, the water is no longer so clear as it was when the rain fell or the snow melted. It has become muddy. Fill a glass full of water from this stream. Then hold it up to the light and look through it. You can see why it is muddy. Thousands of tiny specks are floating in the water. They are bits of soil. They were washed away from the land by the water. Now let the glass stand for several hours. Notice that the soil sinks to the bottom.

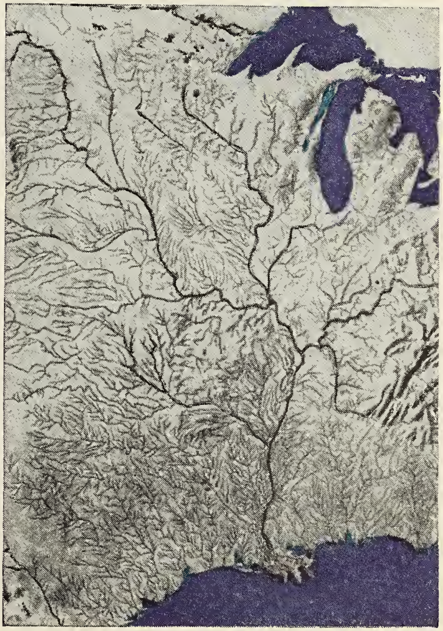
If you pour the water back into the stream, the soil will again start on its way downhill with the water. Some of the soil will sink to the bottom of the stream. Some may be carried to a river or even to the ocean before it settles to the bottom. The next time it rains, see if you can find a place where water has moved some soil. Look on your school playground or around your home. Perhaps you can find soil that was washed onto the sidewalk or into the street.

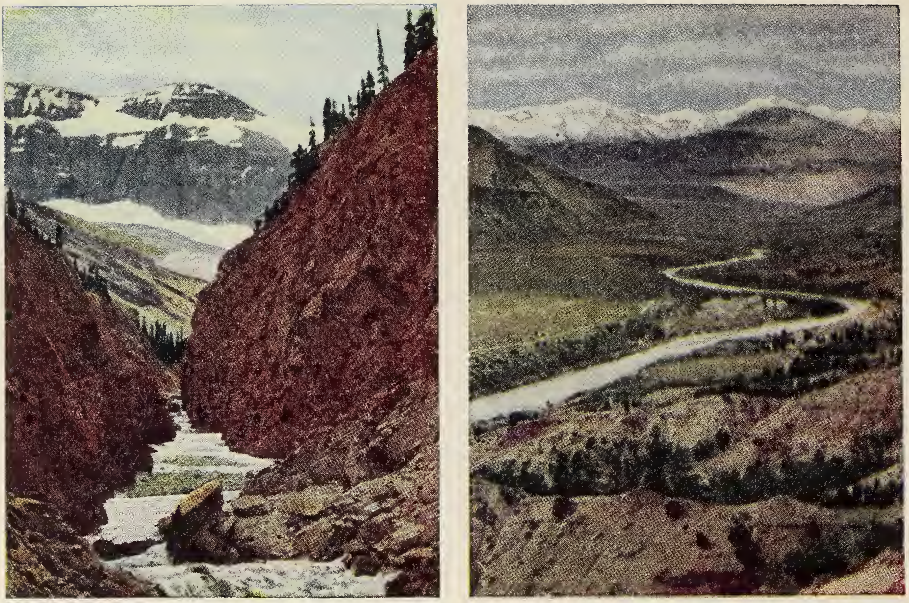
You can see that water moves soil if you have a sand table in your schoolroom. Or you can use the sandbox on the playground. Make a pile of sand. Then pour a bucket of water on it. Watch the water run down. Notice that the water moves some of the sand along with it.

One of the greatest movers of soil is the Mississippi River. Look at the picture on this page. It shows the Mississippi River and the streams that come together to make it. You can see how the small streams join to make larger streams. Notice how the larger streams come together to make the Mississippi. The water in all these streams is moving soil from higher places to lower places. Some of the soil is carried from the northern United States all the way to the Gulf of Mexico, which is part of the Atlantic Ocean.

In one day, this great river carries more than a million tons of soil into the ocean. If men tried to move all this soil in one day, they would need 7500 big trucks. And each truck would have to dump a load of soil into the Gulf of Mexico every hour to get the job done.

Not all of the soil is carried to the ocean. Some of it settles to the bottom, or *bed,* of the river. As time goes on, places in the river become shallower and shallower. Sometimes islands are





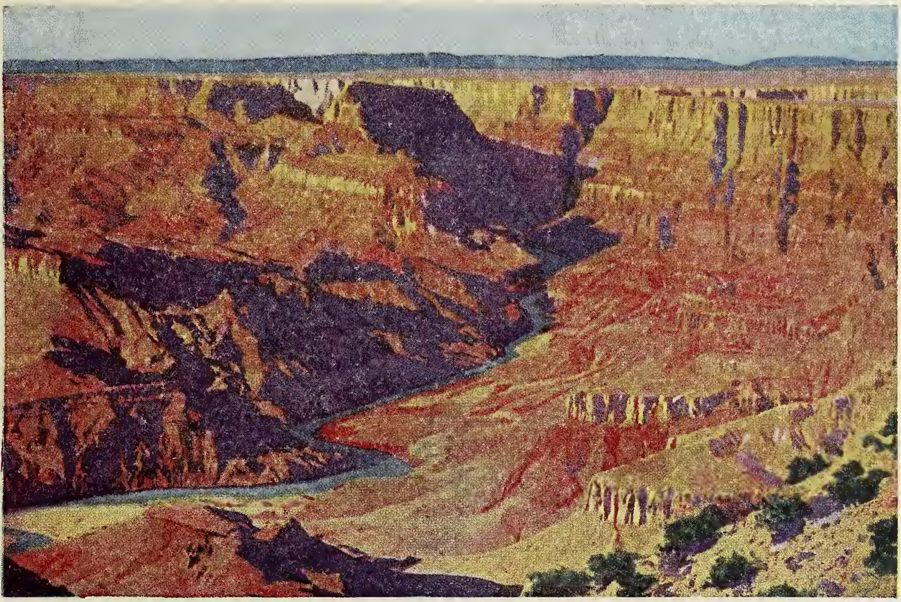
After you have read these two pages, tell which of these valleys is older.

formed. Trees and other plants grow on the islands. At other times, there are floods. Then water rushes out over the banks of the river onto the land. Soil settles from the water. When the floods are gone, much rich soil is left on the fields along the river.

When water flows swiftly, it can move things bigger than bits of soil. Did you ever watch a stream rushing down a mountain? If you looked at the bed of the stream, you probably noticed that it was covered with stones. Many of the stones came from farther up the stream. They were broken from big rocks. Then they were rolled along by the water as it rushed down the mountain.

The moving water wears away the stones. As the water rolls them over and over, they rub against each other. Tiny bits of rock are broken off, and the water carries them away. So a piece of rock high up on a mountain can be slowly ground into bits. Then water carries these tiny pieces down into a valley, where they make part of the soil.

Running water sometimes uses stones for tools, too. As the water rolls the stones along, they scrape against the bed of the stream. In this way, the stones dig out the soil on the bottom. A stream that flows swiftly wears away its bed. As the years go by, the bed becomes deeper and



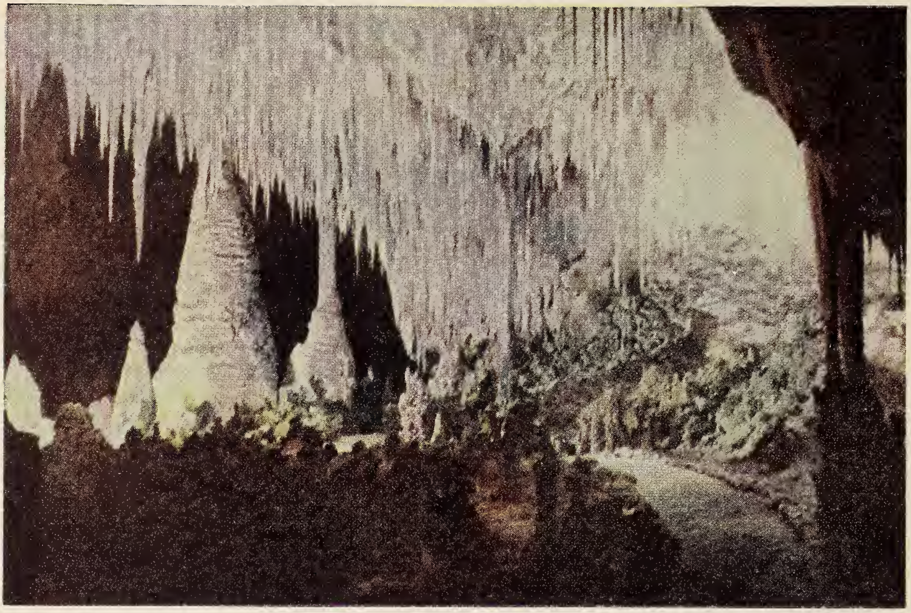
It took many thousands of years for the Colorado River to dig the Grand Canyon.

deeper. The moving water makes a valley. At first, the valley may be shaped like a V. Then the valley becomes wider and flatter. Look at the pictures of valleys on these pages. You will see several kinds.

One picture shows the deep valley of the Colorado River. It was cut through solid rock. In places, the valley is more than a mile deep. Such a deep valley as this is called a *canyon.* Thousands of years ago, the Colorado River began to dig its deep bed. In one year, this big river does not make enough change in the earth's surface for you to notice. But the river has flowed over the land for many, many years. During that time, it has carried away millions of tons of rock and made this great canyon.

In some parts of our country, caves have been cut into the rock below the earth's surface. Perhaps you have visited Mammoth Cave in Kentucky, Luray Caverns in Virginia, or Carlsbad Caverns in New Mexico. If you have, you saw another way in which water helps change the earth's surface. Caves like these are formed where the rock is limestone.

This is how the caves are made. Carbon dioxide in the air dissolves in water on the earth's surface and makes an acid. The water with the acid in it runs down through cracks in the limestone. Then a chemical



change takes place. The acid changes the limestone, and it slowly dissolves in the water. As the water carries it away, the cracks become larger and larger. After millions of years, caves are formed in the rock.

Water will also dissolve chemical compounds that are in the soil. Some of these compounds are given out by the roots of plants. Others come from plants that have died and decayed. When these chemicals are dissolved in water, they can change rocks. Some rocks are softened. Others are slowly dissolved. Then these rocks can be broken up or worn away more easily.

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1. *After there has been a heavy rain or when snow is melting, why are streams usually muddy?*
2. *The stones found along rivers are usually smooth and round. Why?*
3. *In what two ways does moving water change the earth's surface?*
4. *Explain how pieces of a big rock that is now on top of a mountain may someday be at the bottom of the ocean.*
5. *Why is the bed of a mountain stream usually covered with stones instead of mud?*
6. *How are caves like the one shown on this page, made in the earth?*

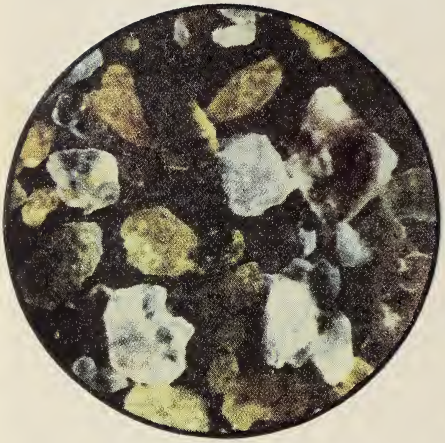
These large sand hills were made when the wind moved the sand and piled it up.

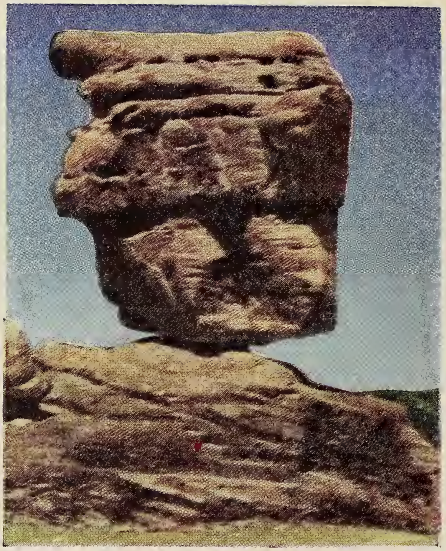
How does wind change the earth's surface?

YOU CANNOT SEE one of the great movers of the earth's surface. But you can feel it, and you can see what it does. Of course, this mover is wind. You know that wind is just moving air. It can turn windmills and push sailboats. And it can move parts of the land, too.

Perhaps you live in some part of our country where there have been terrible dust storms. Huge clouds of dust are blown along by the wind. The dust is soil. When the wind blows over dry land, it picks up bits of soil and carries them away. In these dust storms, thousands of tons of soil have been moved from one place to another. Sometimes the soil is piled over roads, fences, houses, and barns. At other times it may be carried for hundreds of miles. Soil from Kansas and Oklahoma has been blown all the way to New England.

In some places, the wind piles sand up into hills. These sand hills are called *dunes*. They are usually formed along the shores of lakes and seas. At the southern end of Lake Michigan, there are dunes over 200 feet high. Dunes sometimes cause damage when the wind makes them move inland from the shore. They may travel





This rock, called Balanced Rock, is in the Garden of the Gods in Colorado. Sand blowing against it wore away the soft parts and left the rock in this strange shape.

as much as fifty feet in a year. As they move along, they bury plants, streams, roads, and houses. But when grass, trees, and other plants cover these sand hills, the dunes stop moving.

If you have a sand table or a sandbox, you can see how dunes are made. Stick a small board and some twigs in the sand near one end of the table or box. Set a small electric fan close to the sand. Start the fan and watch what happens to the sand. Does the wind from the fan blow the sand along? What happens to the sand when it hits the board and the twigs?

This is how dunes are made. The wind picks up some sand and carries it along. Then the moving sand comes to a little hill or to some bushes or trees. These stop the sand, and it falls to the ground. Or sometimes the wind slows down. Then it cannot keep the sand in the air. So the sand drops. As time goes on, the wind carries more and more sand to the same place. The dune becomes bigger and bigger.

Wind changes the earth's surface in still another way. Look at some sand with a magnifying glass. You will see something like the picture on this page. Bits of sand have sharp edges unless water has worn them smooth. You know that sandpaper will wear away hard wood or even soft metal. When the wind blows sand against rock year after year, the rock is slowly worn away.

The pictures on these two pages show rocks that have been worn away by wind and sand. For hundreds of years, the wind has blown sand against these rocks. The softer parts of the rocks have been worn away, and the harder parts have been left. That is why these rocks have such strange shapes.

Both moving air and moving water change the earth's surface. They carry soil and bits of rock from one place to another. They break up rocks and grind them to pieces. Scientists have a name for all this wearing away of the earth's surface. They call it *erosion*. It is one of the ways in which the earth's surface is changed.

---

1. *Give two ways in which wind changes the earth's surface.*
2. *How are sand dunes made?*
3. *Tell in your own words what* erosion *means.*
4. *Which of these things can only wind do? Which can only water do? Which can both wind and water do? Explain your answers.*
    - *a) Move sand and soil from one place to another.*
    - *b) Move rocks from one place to another.*
    - *c) Wear away rocks and grind them to bits.*
    - *d) Move sand and soil to higher places.*

The Athabaska glacier in Canada is one of the largest glaciers in North America.

How has ice changed the earth's surface?

WHEN WATER FREEZES, it turns to ice. You already know that freezing water can split rocks into pieces. Ice changes the earth's surface in other ways, too. Like wind and water, ice causes erosion. It can move soil and rocks from one place to another. And it can also make lakes and hills. Let us see how these things happen.

Ice covers some parts of the earth's surface all through the year. Even in summer, it is not warm enough for all the ice to melt away. The land around the South Pole is always covered with ice. In some places, the ice is two miles thick! A huge sheet of ice covers most of the big island of Greenland in the north Atlantic Ocean. This sheet of ice is several thousand feet thick near the center of the island. Other thick layers of ice are found in the Rocky Mountains of Canada and in Alaska.

Scientists have a name for a sheet of ice that covers the land. They call it a *glacier*. Strange as it seems, glaciers can move. But, of course, they do not move very fast. They travel only a few feet a year. The glaciers in

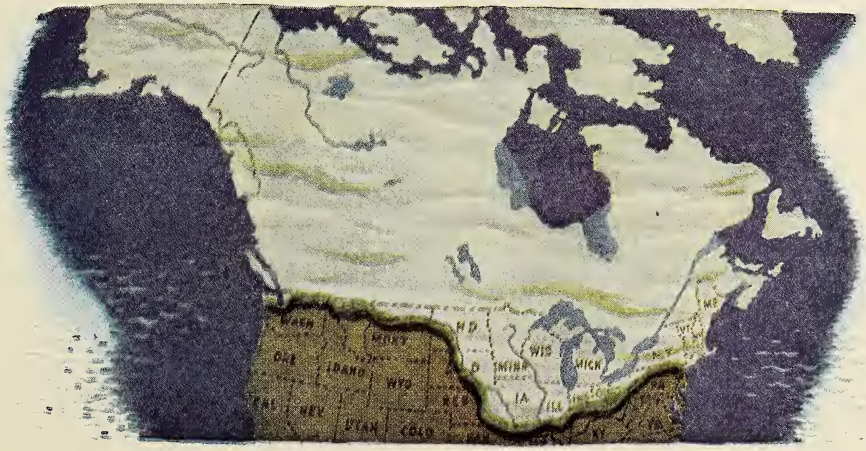
Alaska, Greenland, and the regions near the South Pole slowly push their way toward the ocean. As they move along, more and more ice is pushed out into the water. At last, huge chunks break off and float away as icebergs. In the mountains, glaciers slowly move down into the valleys. It is warmer there. So the ice melts, and the water flows away in mountain streams.

Thousands of years ago, much of North America was covered with ice just as Greenland and the South Pole are today. Down from the north, a glacier slowly moved like a huge river of ice. It pushed its way over Alaska and Canada. Then it spread out into what is now the United States. At last, it got as far as where the Ohio River now flows.

As the glacier moved along, it wore away the earth's surface. When it came to a hill, it pushed the top off. Then it crept on its way, carrying a huge load of soil and rocks scraped from the hill. When it came to big rocks, it dragged them along. The rocks rubbed against each other and against the earth. Some were broken into pieces or ground to bits. Others were flattened or scratched. The glacier pushed forward with its load. It scraped and scooped out great holes in the earth's surface. And it leveled off high places. On and on it went.

After many thousands of years, the weather became warmer. The glacier stopped moving forward. Slowly it began to melt back. There was much water from the melting ice. The water ran down into the low places that the glacier had dug in the earth. This water made lakes. The Great Lakes and many smaller lakes were made in this way.

As the glacier melted back, it left behind its load of soil and rocks. In



This pile of rocks is a moraine that was left at the end of a glacier.

many places, a thick layer of rich soil was left. Some of the best farm land in our country was made in this way. Huge rocks that were dragged all the way from Canada can be found as far south as the Ohio River. In some places, the glacier made high hills. Ridges of rocks were left at the sides and the end of the glacier. These ridges are called *moraines.*

Before this glacier came and went, at least three other great sheets of ice had moved down from the north. But scientists do not know much about any of these glaciers except the last one. The map on page 79 shows the parts of North America that were covered by the last glacier. Did it cover the place where you live?

Someday you may take a trip through the parts of our country that were covered by the last glacier. You will see the moraines left by the great sheet of ice. You will also see many lakes in the holes that were dug out by the glacier.

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1. *Name some places where glaciers are found today.*
2. *How does ice move soil and rocks from one place to another?*
3. *Why does it take so long for a glacier to make changes in the earth's surface?*
4. *How did glaciers help make lakes and hills?*
5. *What is a* moraine?

How do volcanoes build up the earth's surface?

FOR MILLIONS OF YEARS, erosion has gone on all over the earth's surface. Rocks are broken up. Hills and mountains are worn down. Water carries soil, sand, and even rocks to lower places. Ice does the same thing. Only wind can lift sand and soil. But it cannot lift them higher than a few hundred feet.

Perhaps you are wondering why the earth is not just a big level plain by now. Here is the reason. Erosion does level off the land. It wears down the high places, and it fills in the low places. But erosion is not the only way in which the earth's surface is changed. Other changes push parts of the earth up. This story will tell you how one of these changes in the earth's surface takes place.

One day, just a few years ago, a Mexican farmer was working in his cornfield. All at once, he felt the ground shake. Then he heard a strange, rumbling noise. From a small crack in the earth, a thick cloud of dust poured out like smoke. The farmer was frightened. He ran to the little village of Paricutin, about two miles away.

Later that day, he came back with some people from the village. The crack in the earth was now a big hole. Tons of hot rocks and ashes shot out of it high into the air. Some of the rocks and ashes fell around the hole and made a sloping pile shaped like a cone.

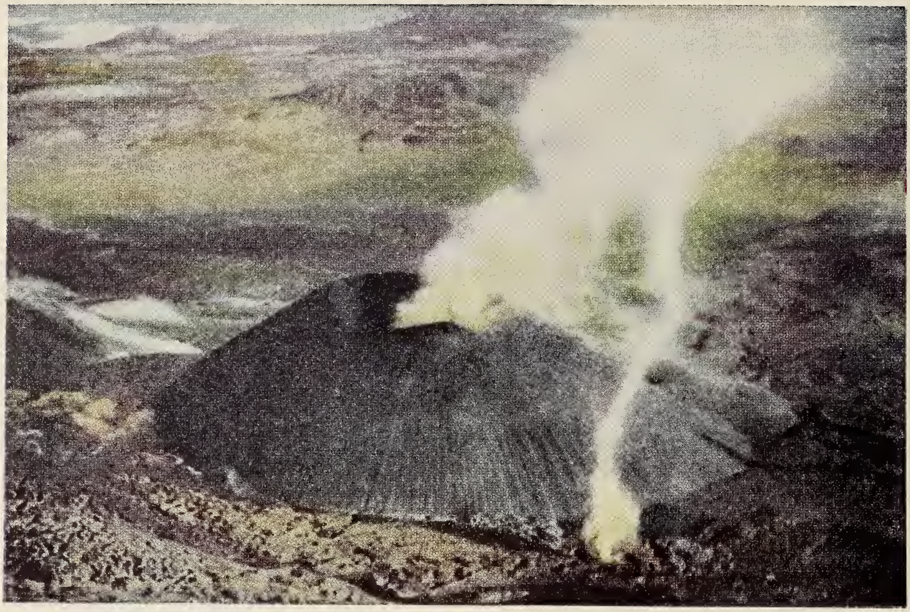
The hot rocks and ashes kept on piling up. In three days, the cone was 120 feet high. By the end of a week, it had grown to 500 feet. In ten weeks, it was 1000 feet high. By now, it is over 2000 feet high and still growing.

The cone was soon filled with hot, liquid rock. It flowed over the top and ran down the sides. In places, this stream of hot, liquid rock was fifty feet deep. Moving about twenty feet an hour, it traveled for seven miles and destroyed two villages.

A new *volcano* had been formed! It was called Paricutin after the little village nearby. Scientists came from many different places to watch it build up the earth's surface. They are keeping careful records of what happens. From the records, they hope to learn many new things about volcanoes.

No one knows just how a volcano is made. But scientists believe that something like this happens. As you know, the inside of the earth is very, very hot. In some places, it is so hot that solid rock melts and changes to a liquid. You have already learned that igneous rocks are formed from hot, liquid rock.

Sometimes the liquid rock has steam and other gases in it. The liquid rock and the gases are lighter than the solid rock around them. So the solid rock sinks. This forces the liquid rock and the gases up. They push against the rocks above them with



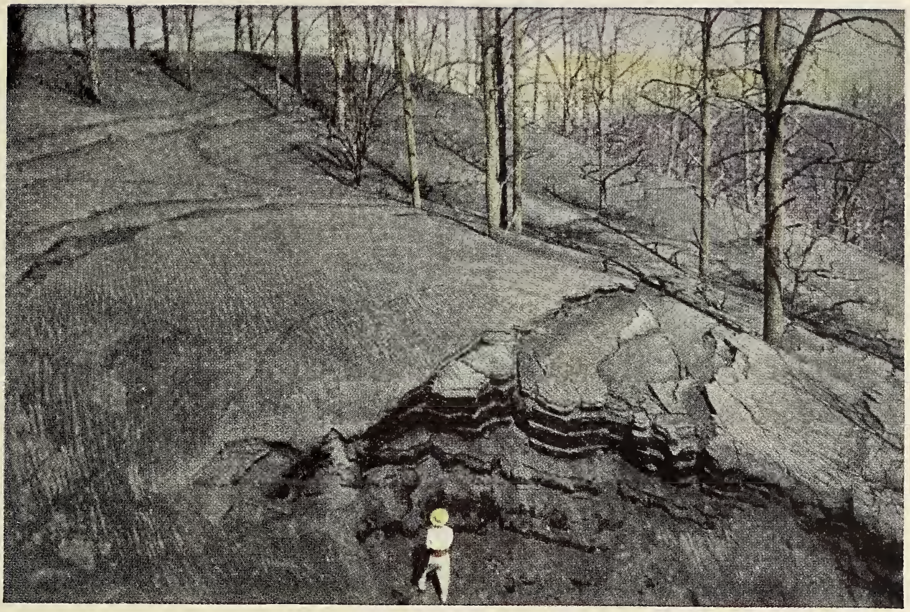
Paricutin grew very rapidly. In a few months, this huge cone of ash and lava had grown up where there had been only a flat cornfield.

great force. If there is a weak spot or a crack in the earth's surface, the gases and the liquid rock pour out. Then a volcano is formed.

If the weak spot or the crack is small, the gases and the liquid rock cannot get out fast enough. Then the volcano explodes. We say that it *erupts*. Erupt means burst out. Hot rocks and ashes shoot into the air. The material that looks like ashes is called *volcanic ash*. It is made from rock that was blown to bits by the explosion.

Steam from a volcano sometimes condenses into water and makes mud out of volcanic ash. Then it "rains" mud around the volcano. The wind carries dry volcanic ash to places far away. Ash from Paricutin fell in Mexico City, 200 miles from the volcano. For thirty-five miles around the volcano, there is a layer of ash. In some places, it is nine feet deep. As it piled up, it crushed buildings and buried farms.

Hot rocks and volcanic ash fall around the hole made by a volcano. They form a sloping pile shaped like a cone. Each time the volcano erupts, more rocks and ash are added to the pile. A mountain builds up around the hole. The top of the mountain is hollowed out like a bowl. This hollow



This picture shows what a thick layer of ash has fallen around Paricutin. The ash has killed the trees and other plants and has buried everything in the countryside.

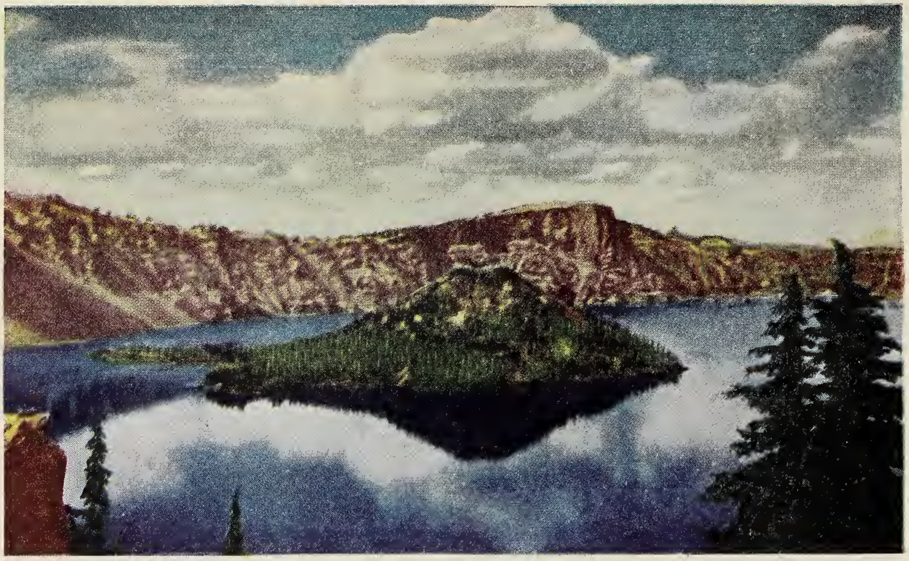
place in the top of the mountain is called the *crater* of the volcano.

Mount Shasta and Lassen Peak in California, Mount Hood in Oregon, and Mount Rainier in the State of Washington are old volcanoes. All of them are at least 10,000 feet high. These old volcanoes do not erupt any more. But Lassen Peak did send up steam and mud about thirty-five years ago. Beautiful Crater Lake in Oregon was formed when water filled up the crater of an old volcano.

Rocks and ash from volcanoes help build up the earth's surface. So does the hot, liquid rock from deep inside the earth. This hot, liquid rock is called *lava.* It pours out on the land. Then it cools and hardens again into solid rock, or lava. Not all the lava comes from volcanoes. Some flows out through cracks in the earth.

Millions and millions of tons of lava have poured out on the land in many parts of the world. In some places, the lava is very thick. The Snake River in Idaho has cut a deep canyon. In the walls of the canyon, scientists have counted thirty different layers of lava. Each layer was formed when hot, liquid rock flowed out of the earth.

If you live in Oregon, Washington, Idaho, or California, the soil in parts of your state was once inside the



This is Crater Lake in Oregon. The island in the lake was made by a small cone that was formed in the center of the crater.

earth. The rock from which this soil was made came out of the earth and spread over the land. In some places, volcanic ash settled on the land and was slowly changed into soil. In other places, lava flowed over the land.

After the rock had cooled, it was worn down and broken up. The wind, the rain, the sun, and the plants slowly crumbled the hard lava. It was changed into part of the soil. This soil is usually very rich. In Canada, there is a place 900 miles long and 100 miles wide where the soil was made from lava. Much of the rich soil in the Hawaiian Islands was made from lava.

1. *Tell in your own words how a volcano is formed.*
2. *How do volcanoes build up the earth's surface?*
3. *Why does it sometimes "rain" mud near a volcano?*
4. *Is lava igneous rock? Why do you think so?*
5. *What is volcanic ash made of?*
6. *An old volcano no longer erupts. How do you think scientists know that it is a volcano?*
7. *How is soil made from rock that was once inside the earth?*

How are mountains made?

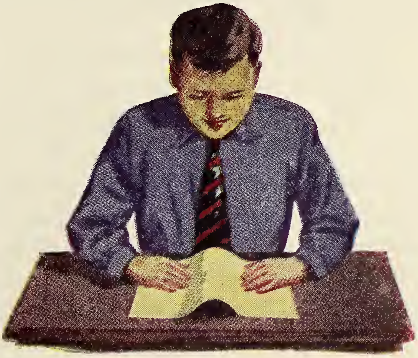
LOOK AT THE PICTURE at the right. It shows what is left of a fish that lived in the ocean millions of years ago. Scientists call it a *fossil,* which means the hardened remains of any animal or plant. The fossil of this fish was found in a sedimentary rock on a mountain 2000 feet above the ocean. How did the fossil get there?

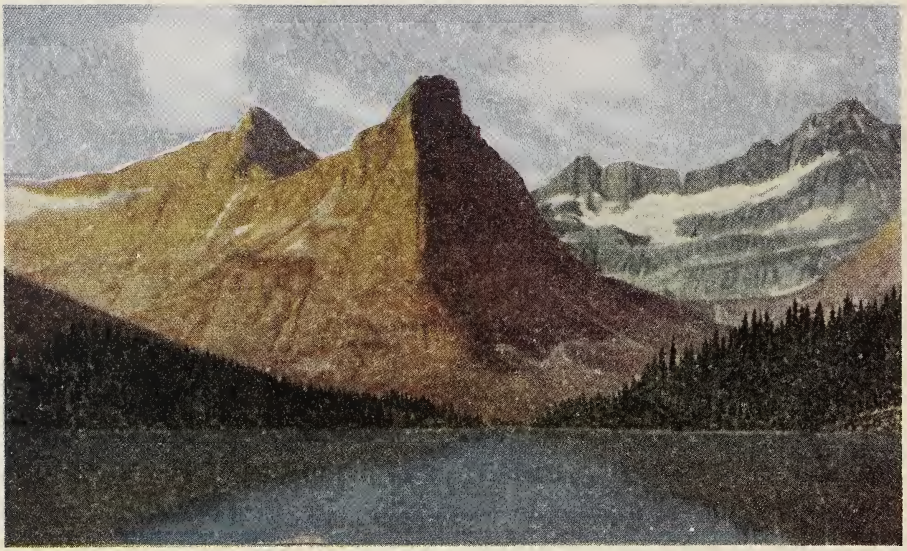
Scientists know that the fish lived in the ocean. When it died, it sank to the bottom and was covered with sediment. After a long, long time the sediment was changed to rock. But how did the rock with the fossil in it get up on a mountain? Scientists believe that some great force or forces pushed the rock up and made a mountain.

What the forces were that made mountains, scientists do not know. But let us see how they think some mountains were made.

Do this experiment. Take a sheet of paper and lay it flat on your desk or a table. Put your hands on the ends of the paper and push them toward the middle. What happens to the paper? It rises in a ridge near the middle.

Scientists believe that some mountains were made in this way. One reason that they believe it is this. They have found layers of sedimentary rock bent up like the ridge in the paper. When the layers of rock were formed under the ocean, they were not bent. If the rock had been pushed straight up, the layers would not be bent. So scientists think that some force pushed sidewise on the rock and bent the layers to form the ridge.





How are these mountains different from the ones you see on the next page?

Just how this sidewise force was produced, scientists do not know. But one thing seems to help explain it. Rocks found under the ocean are heavier than rocks found in the land. Scientists think that the heavier rocks sank and pushed against the lighter rocks. Then the lighter rocks were bent upward.

Scientists know that the inside of the earth is much hotter than the outside. They think that the outside was once much hotter than it is now. As the outside became cooler, it contracted and shriveled up like the skin of a dried apple. This left cracks and ridges in the earth's surface. If this change really happened, the ridges would be the mountains.

In our country, there are mountains in the east and mountains in the west. The mountains in the west were made long after the mountains in the east were made. So they are called young mountains. Scientists believe that the young mountains in the west are still getting bigger. They are sure that the old mountains in the east are not getting bigger. These mountains were once nearly six miles high. Now they are less than two miles high. Do you know what wore them down?

Probably you are wondering how scientists tell whether a mountain is young or old. You know that erosion is always changing the earth's surface. Heat and cold, wind, water, and ice are all wearing away the rocks. But

The old mountains in the eastern part of our country look like these.

young mountains have not been worn down so much as old mountains. The young mountains are still sharp and jagged. The old mountains have become smooth and rounded, as you can see from the pictures.

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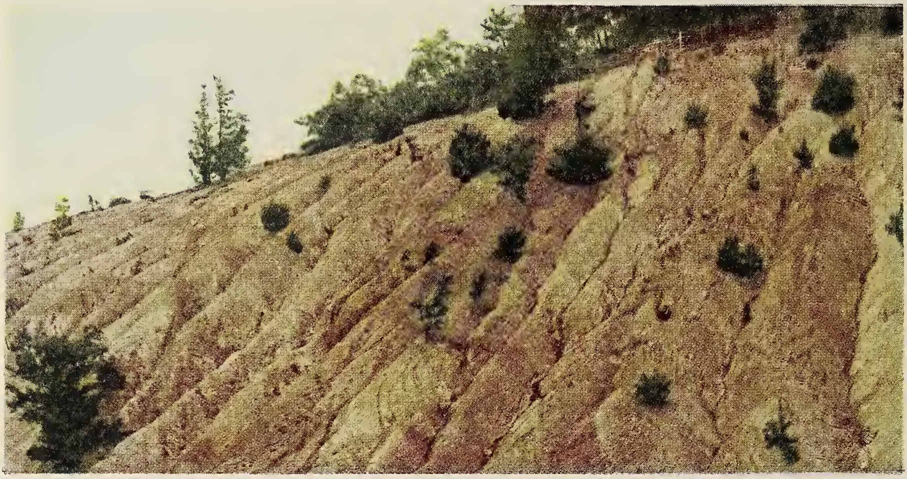
1. *Why do scientists believe that some mountains were made when rocks were pushed up?*
2. *How can scientists tell whether a mountain is young or old?*
3. *Why do you think scientists study the fossils that they find in rocks?*

How can we conserve the soil?

A THIN LAYER of soil keeps us from starving. Green plants grow in the soil. From it, they take water and minerals to use in making their food. All things that live on land get food from these green plants. Or they get it from other living things that use the green plants for food.

Besides making food, green plants supply materials for clothing and shelter. Of course, you know that we get cotton and linen from these plants.



Watch to see if there are any places that look like this near your home.

p 73

But did you ever stop to think that they help supply us with wool and leather? We get wool and leather from animals that eat green plants. All the wood that we use for building and for fuel comes from green plants, too.

You can see why we need the soil. Without it, there would be no green plants to keep us alive and comfortable. But do you understand why we must conserve the soil? Perhaps you are wondering what could possibly happen to it.

Our country once had more than 600 million acres of good farm land. At least 150 million acres have already been ruined. The green plants that we need will no longer grow there. We still have more than 450 million acres of good farm land. But all but about 80 million acres of this land has been damaged. Today our government and thousands of people are fighting a hard battle to conserve the soil that is left. Let us see what puts this soil in danger.

Ever since the earth was formed, its surface has been changing. As soon as any part of the earth's surface is built up, erosion begins to wear it down. Rock is broken up and carried away. Some of the rock is made into soil. Erosion takes thousands or even millions of years to wear down a mountain of rock. But it can carry away soil much faster.

Look at the picture on this page. Little valleys, called *gullies,* have been made in the side of a hill. Can you tell what made them? Rain fell on the hard, bare ground. It could not soak into the soil very fast. So it be-

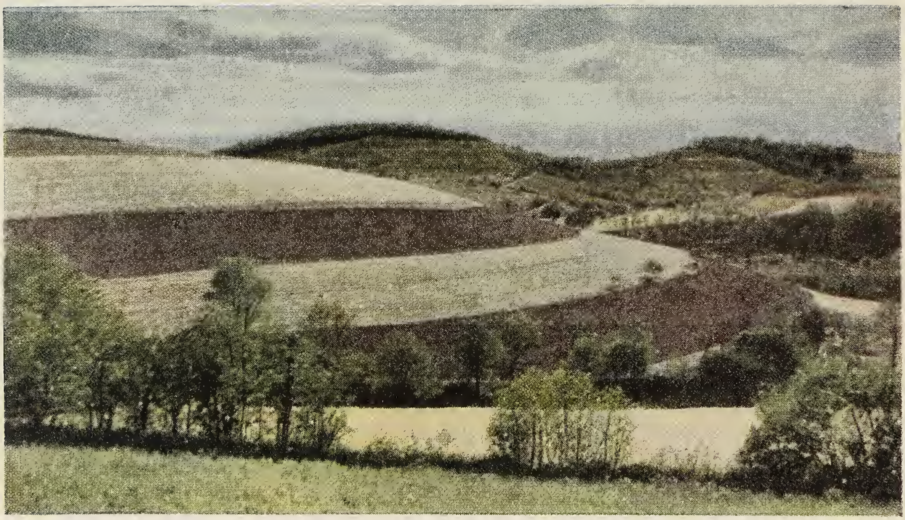
The dark cloud is not smoke. It is a dust storm coming toward the houses.

gan to run downhill in little streams. It carried the soil along with it and dug gullies in the hillside. Erosion by moving water is at work here. This erosion is not slow. It takes place much faster in soil than in solid rock. In only a few years, tons and tons of soil are carried away by moving water. No wonder a scientist once said, "Soil is rock on its way to the ocean."

Water can easily carry soil away from a steep hillside. But it can also carry soil away from a gently sloping field. This happens when the soil is bare or when the crops are not properly planted. Then a farmer can no longer use the field to grow plants. The thin layer of soil on top is the only place where plants will grow well. They cannot grow well in the soil that is deeper down. When the rich soil on top is carried away or when the field is cut up with gullies, the land is almost useless for growing crops.

Erosion also moved the soil in the picture on this page. But the soil was not carried by moving water. Wind blew it away from nearby farms. The ground was bare, and the soil was dry. Wind picked up the dry soil and carried it away. Sometimes the wind carries away huge clouds of dry soil and makes dust storms. Erosion by wind does the most damage in places where there is not much rain.

Hundreds and hundreds of farms have been ruined by erosion, and many more have been badly damaged. This is what often happens. A farmer has a good piece of land with



rich soil. He cuts down the trees to get more room for crops, and he plows up the grassland. His cows, sheep, and other farm animals eat the grass in the pasture too close to the ground. Then wind and water carry the soil away.

Scientists say that it takes 500 to 1000 years to make a layer of good soil one inch deep. In a few years, erosion by water or wind can carry this thin layer away. Nearly four billion dollars' worth of soil is lost from our country in this way every year. Something must be done to stop erosion of the soil. Let us find out how it can be stopped.

In most places, erosion by moving water does much more damage than erosion by wind. Of course, no one would want the rain to stop falling or the snow to stop melting. Plants cannot grow without water, as you know. So some way must be found to keep the water from carrying away the soil. Running water must be made to walk.

Huge dams have been built across many rivers in our country. The dams control the flow of water and help prevent floods. But by the time water gets into the streams, it has already damaged the soil. The place to stop erosion is on the land. Scientists and farmers have worked out several ways to do this.

The picture on this page shows one way to stop erosion by water. Look at the picture carefully. Then try to tell how water is kept from carrying away the soil. Do you see that the rows of crops are planted *across* the slopes of the hills instead of *up and down* the slopes? When it rains, these rows hold the water back like tiny dams. Then the water has time to soak down into the soil instead of running off and carrying the soil with it. This also saves much water for the plants to use in growing.

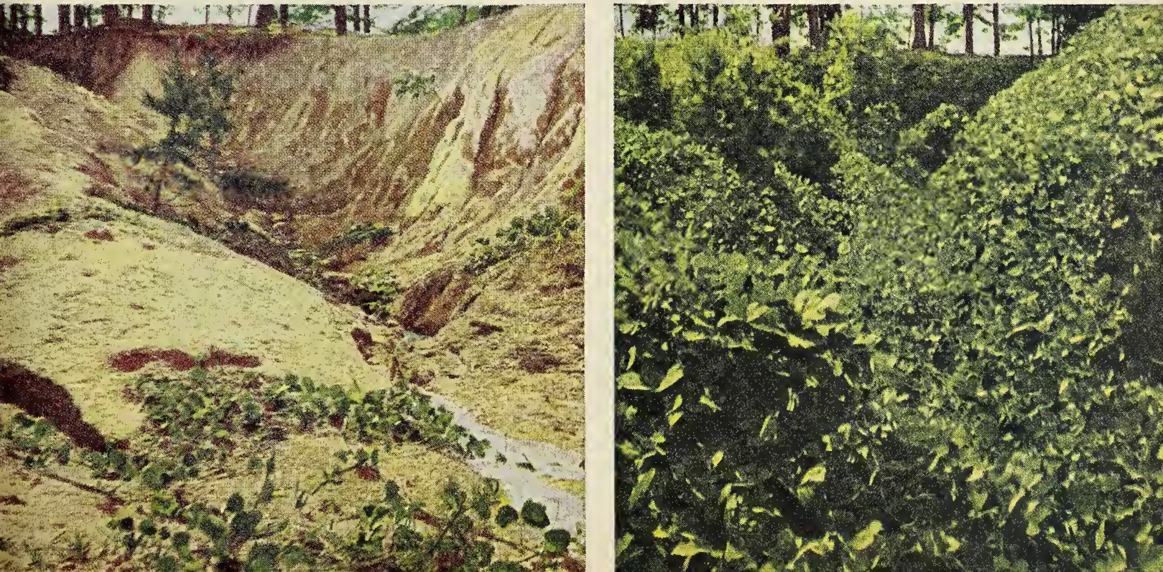
Plants help keep the soil from being washed away, too. Pour a bucket of water on a slope that has no plants growing on it. The water that runs down to the bottom of the slope will be muddy. The moving water has carried some of the soil away. Now pour a bucket of water on a slope that is partly covered with plants. This time the water carries away very little soil. The roots hold the soil that is near the plants.

A thick covering of grass will keep most of the water from running off the land after a heavy rain. The grass breaks the fall of the water. So it strikes the ground more gently. Very little of the water runs off into streams, carrying soil with it. Most of the water soaks into the ground. Even on hillsides, grass makes the water flow off more slowly. Farmers plant grass on hillsides and use the grass for pasture.

Like grass and other plants, trees help keep water from running off the land too fast. The leaves, twigs, branches, and trunks break the fall of the water. So the water trickles slowly to the ground. Then it sinks slowly through a mat of dead leaves and branches into the soil. Very little of the soil is washed away, and much water that plants need is saved.

Plants such as trees and grass also help keep the wind from carrying away the soil. A row of trees will break the force of the wind. Grass covers the soil with a net of roots and holds it together. Then the wind cannot carry it away. Wind cannot

The vine that was planted in this gully will keep the soil from washing away when it rains.



blow soil that is covered by forests or thick grass. But where forests have been cut or burned and grasslands have been plowed, wind can ruin thousands of acres of good soil. Look again at the picture on page 89.

Here are three good rules to follow if you want to keep soil from being washed or blown away. Do you see why they are good rules?

1. Plant trees on steep slopes.
2. Plant grass on rolling slopes.
3. Plant crops on gentle slopes and flat land.

Our government spends millions of dollars every year to prevent erosion of the soil. On land where crops will no longer grow, trees and grass are planted. Farmers are urged to conserve the soil, and scientists show them how to do it. Much good work has already been done to protect the soil from erosion, but there is still a great deal of work to do. Luckily for us, it is not too late to save most of the soil. One scientist said, "We have enough soil to take care of us if we take care of the soil."

1. *Why must we conserve the soil?*
2. *In what two ways is good soil carried away?*
3. *How can we help stop erosion of the soil?*
4. *Cutting down trees and plowing grasslands have done much damage to the soil. Why?*
5. *Explain why cows, sheep, and other farm animals should not use the same pasture year after year.*

QUESTIONS TO ANSWER

1. Describe the land near you and try to explain how it is changing.

2. Make a list of the changes that take place on the earth's surface. Then answer these questions about each change.

   a) What causes the change?
   b) Is the change fast or slow?
   c) Is it taking place today?
   d) When does the change take place?
   e) Have you ever seen the change taking place?

3. How does gravity help change the earth's surface? Think of as many ways as you can.

4. Explain this statement. *A grain of sand that is now far under the ocean may someday be blown about by the wind.*

5. Some boys once found in a stream what they thought was a round, smooth, red stone. Their teacher told them that it was only a piece of brick. How did it get so smooth and round?

6. Shale and sandstone are formed under water. How did the materials to make them get there?

7. What are four ways in which rocks are broken up and ground to pieces?

8. Is erosion always harmful? Give reasons for your answer.

9. Here are some words that you have learned in this unit. In your own words, explain as clearly as you can what each one means.

river bed
sedimentary
glacier
volcano
canyon
dune
erupt
sandstone
limestone
erosion
lava
metamorphic
crater
fossil
gully
igneous

THINGS TO DO

1. If you have taken a trip through our country, tell your class about some of the things you saw that you learned more about in this unit.

2. Find out what happens as the Mississippi River empties its load of soil into the Gulf of Mexico.

3. If you can get a piece of lava, look at it carefully.

4. Read about some famous volcanoes such as Vesuvius, Etna, Krakatoa, Pelée, Chimborazo, Mauna Loa, and Fujiyama.

5. Look for pictures in newspapers and magazines that show changes in the earth's surface. Make a scrapbook of the pictures. Under each picture, write a few sentences that tell what it shows.

6. If someone in your class has visited Grand Canyon, Bryce Canyon, or Yellowstone Canyon, or some other large canyon, ask him to tell the class about it. Or find some pictures of these canyons and look for the river at the bottom of each one.

7. Use a hammer to break a rock. Notice how sharp the edges of the pieces are. Is the rock a different color on the outside? Why?

8. Collect pictures of glaciers. Find out how each glacier is changing the earth's surface.

9. Find out how terracing, strip cropping, and contour plowing prevent soil erosion.

10. Read to find out how winter cover crops such as rye and wheat help prevent erosion of the soil.

11. Find out about quartz, mica, and feldspar. What kinds of rocks contain these minerals?

★ *In Unit Four You Will Learn* ★

★ *How scientists have learned about germs* ★
★ *How you can grow bacteria* ★ *How germs get into your body* ★
★ *How your body fights germs* ★
★ *How scientists help your body fight germs* ★
★ *How we can keep germs from spreading* ★

★ UNIT 4 ★

How Do Germs Make You Sick?

A DEADLY KILLER was at work when American and British soldiers reached Naples, Italy, in September 1943. Hundreds of people were sick and dying. The killer was a disease that scientists call *typhus*. During and after wars, millions of people have died from this disease.

Our doctors knew what might happen, and they were ready for it. Within a month they had the disease under control. Not one soldier died from typhus! Most of the people in the city were saved, too. Scientists had discovered how to stop typhus. How do you think they did it?

You probably want to learn the answers to some other questions, too. How do typhus and other diseases make people sick? Where do they get the diseases? Can the diseases be cured?

The girls in the picture on page 94 are helping scientists find the answer to the last question. They are testing a new drug to find out what germs the drug will kill and how much of the drug it will take.

Make a list of all the questions that you would like to have answered about diseases. As you study this unit, try to answer your questions.

How have scientists learned about germs?

YOU ALREADY KNOW more about germs than the greatest scientists knew 100 years ago! You have learned what germs are and what they do. Germs are very tiny plants or animals. When they get inside your body and grow, they can make you sick. Many diseases are caused by germs. One kind of germ causes one disease, and other kinds cause other

diseases. It took scientists a long time to discover these things about germs. Let us see how they did it.

The story really begins in Holland nearly 300 years ago. Here a man named Anton van Leeuwenhoek had a hobby of grinding *lenses.* A lens is a curved piece of glass. One day, Van Leeuwenhoek put two lenses together. When he looked through them, he discovered that they made things appear much larger. With these lenses, he could see many things that could not be seen at all with the naked eye. On this page is a picture of Van Leeuwenhoek with one of his lenses.

Van Leeuwenhoek looked at many different things with his microscope to see what he could discover. He looked at a fly's head, a bee's stinger, and a hair from his own head. One day, he put a drop of pond water under the lenses. When he looked through them, he called to his daughter in surprise, "See these thousands of little animals." He was the first person to see these tiny things. He was sure that they were alive, because he could see them move. But that is all he knew. He never found out what these things are.

Many years later, scientists discovered that some of these tiny things were really plants and not animals. They were the kind of plants we call bacteria. There are many kinds of bacteria. Most of them are harmless, and some of them are even helpful. Bacteria make cider into vinegar, and they change milk into cheese. They also make dead animals and plants decay. But some bacteria are very harmful, as you know. They cause many of the diseases that we have. These harmful bacteria are germs.

For nearly 200 years after Van Leeuwenhoek first saw bacteria, no one ever imagined that they could make people sick. It was only about 100 years ago that scientists discovered that some diseases are caused by bacteria. Two scientists will always be famous for their work in proving that bacteria cause some kinds of diseases. One of them was a French scientist named Louis Pasteur. The other was Robert Koch, a German scientist.

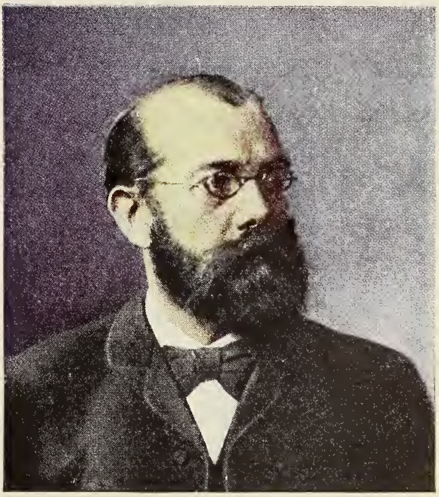
Pasteur was working with some tiny plants called yeasts. He knew that yeasts changed the sugar in grape juice and other fruit juices to alcohol. He was trying to find out why these liquids sometimes spoiled. When he looked at them under a microscope, he found living things even smaller than the yeast plants. These tiny things were bacteria. Then he looked at some sour milk with a microscope and found some other bacteria. Pasteur began to wonder whether some diseases might be caused by bacteria.

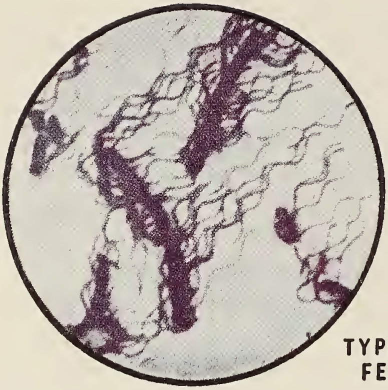
Just about that time, Pasteur was asked to find out why so many silkworms in southern France were dying from a strange disease. Raising silkworms was then the main industry of southern France, and many people earned their living from it. If the silkworms kept on dying by the thousands, the industry would be ruined.

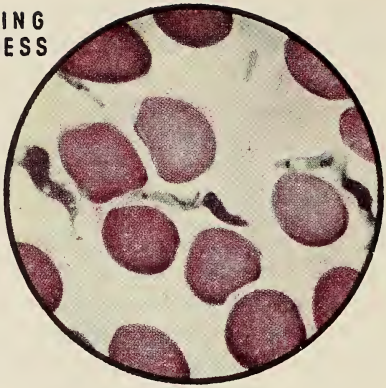
Pasteur studied the silkworms. It was easy to tell which ones had the disease. Their bodies had little dark spots. Pasteur looked at these spots under a microscope and found bacteria in them. Then he fed some of these bacteria to healthy silkworms. They also got the disease! Now Pasteur was sure that the only way to conquer the disease was to get rid of the bacteria. He did this by having all the diseased silkworms killed and their eggs destroyed.

The work of Pasteur saved the French people from losing an industry that was worth millions of dollars. But even more important than that, Pasteur had proved that bacteria can cause a disease in an animal. Not

The picture on the left shows Louis Pasteur in his laboratory. The other picture is of Robert Koch.




TYPHOID FEVER


SLEEPING SICKNESS

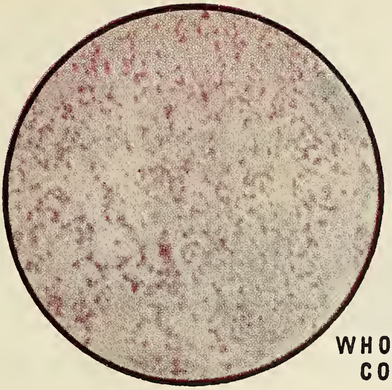
many years later, Robert Koch proved that bacteria can cause some of the diseases people have. The world owes a great debt of thanks to these scientists. Their discoveries have given health to many people and have saved and will save millions of lives.

After Pasteur and Koch made their discoveries, diseases were studied in a new way. Scientists began to do experiments to find out which diseases were caused by bacteria and just what kind of bacteria caused each of the diseases. The experiments were done very carefully. They had to be done over and over again before scientists were sure that a certain disease was caused by just one kind of bacteria.

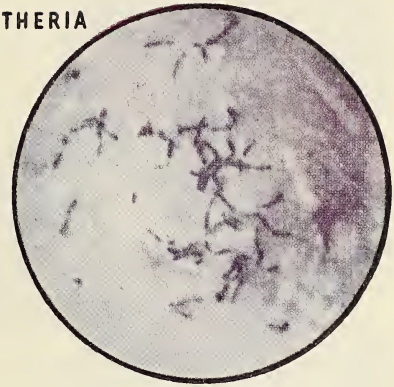
As the years went by, scientists discovered the kinds of bacteria that cause many different diseases. One kind of bacteria causes tuberculosis, another kind causes typhoid fever, still another kind causes diphtheria, and so on through a long list of diseases. Each of these diseases is caused by a certain kind of bacteria.

Scientists also found that bacteria are not the only plants that can cause diseases. Other tiny plants, such as some yeasts and molds, can make us sick when they get inside our bodies. So these plants are germs, too. Besides the plant germs, scientists have discovered animal germs. These are tiny animals that are almost as small as bacteria. One kind of animal germ causes malaria, and another kind causes sleeping sickness.

There are still many diseases that scientists do not know much about. So the search for germs still goes on. For a long time after plant and animal germs were discovered, scientists tried to find the germs that cause diseases like colds, influenza, smallpox, mumps, and measles. Scientists now know that none of these diseases is caused by a plant germ or an animal germ. They have found that each of



WHOOPING COUGH



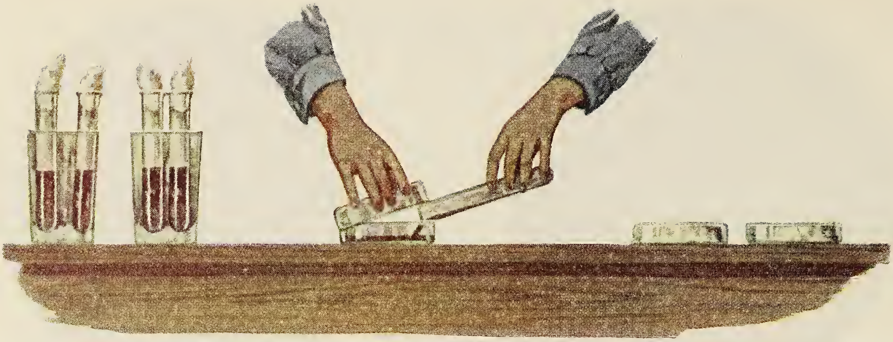
DIPHTHERIA

these diseases is caused by a different *virus.*

Scientists are not sure just what a virus is. They do not even know whether it is alive or not. But they do know that viruses are much smaller than bacteria. They cannot see viruses with the kind of microscope they use to look at bacteria. Diseases that are caused by viruses act like diseases caused by plant and animal germs. So viruses are usually called germs, too.

You must not get the idea that every disease is caused by some kind of germ. Other things besides germs can make you sick. You know that some diseases are caused by eating the wrong kinds of food or by not eating enough of the right kinds. Babies may get a disease called rickets if they do not get enough vitamin D, calcium, and phosphorus. Some people are unusually sensitive to fur, feathers, hair, wool, pollen, leaf mold, certain kinds of food, and many other things. Any of these things can cause a disease called an *allergy.* There are still other diseases that are caused by worry or fear. Later in your science work, you will learn more about these other diseases.

1. *What are germs? Give some examples of different kinds of germs.*
2. *Is each of these statements correct? Explain your answers.*
    - *a) All germs are bacteria.*
    - *b) All bacteria cause diseases.*
    - *c) All diseases are caused by germs.*
3. *Tell how Pasteur discovered germs.*
4. *Why is the work of Pasteur and Koch important to you?*



When you pour the food into the Petri dish, lift the cover just enough to get the test tube in. Why is this an important rule to follow?

How can you grow bacteria?

SCIENTISTS HAD TO DO many experiments to learn about bacteria. You can find out some things about bacteria by doing an experiment, too. You can grow some bacteria. Be sure to follow the directions carefully as you do the experiment.

Get six glass dishes like those in the picture. They are called *Petri dishes.* Put the covers on the dishes and put them into a hot oven for about an hour. The heat will kill any bacteria in the dishes. When you take the dishes out of the oven, be careful not to lift the covers.

Now get some food ready for the bacteria that you are going to grow. Your teacher will tell you how to make it or where to get it. Fill six test tubes half full of the food. Plug the test tubes with wads of cotton. Be sure that the cotton wads are tight in the tubes. Set the test tubes upright in a pan that has three or four inches of water in it. Boil the tubes for about forty-five minutes. Then the heat will have killed all the bacteria in the food. We say that the heat *sterilizes* the food.

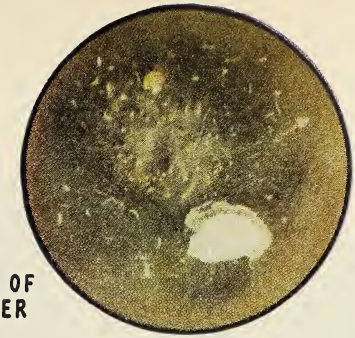
Set the Petri dishes on a table. Be very careful to follow these directions as you fill the dishes. If the food has hardened in the test tubes, heat the tubes in water again. Take the wad of cotton out of a test tube, lift the cover of a dish, and pour the food in. Quickly cover the dish again. Empty the food from a test tube into each dish in this way. The food will soon harden in the dishes. Then you will be ready to grow your bacteria.

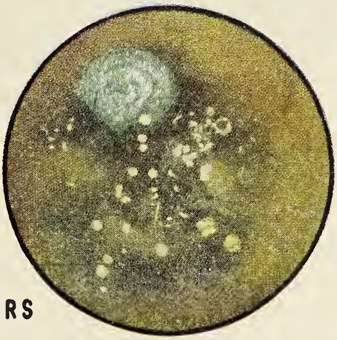
It will be easy for you to get some bacteria to plant in the dishes. But be careful to follow these directions for planting. Plant Dish 1 by lifting the glass cover of the dish and touching the food with a pencil. Quickly put the cover back on and seal it with gummed paper. Put a label on this dish so that you can remember how you planted it. Seal and label each dish in the same way after it is planted.

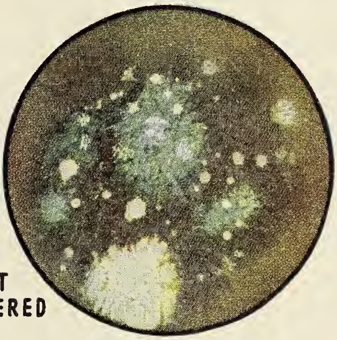
Plant Dish 2 by putting a few drops of milk on the food. After the dish is covered, tip it from side to side so that the milk spreads over the surface. In Dish 3 have someone touch the food with his fingers. Leave Dish 4 open to the air for a few minutes so that the air can touch the food. Plant Dish 5 by touching the food with the flat side of a penny or other coin. If you can get a fly to walk across this dish, you will have an even better planting of bacteria.

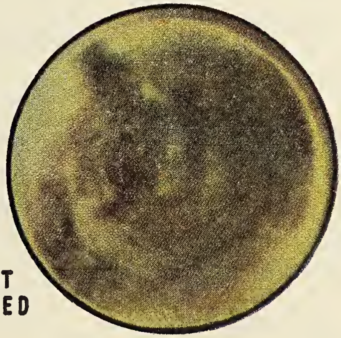
Do not put anything in Dish 6. Seal the dish and keep it sealed. No bacteria should get into it. Do you know why? If the dish is kept sealed and no bacteria grow in it, then you can be sure there are no bacteria in the food. If no bacteria grow in this dish but do grow in the other dishes, you will know that the bacteria in the other dishes must have come from the pencil, the milk, the fingers, the air, and the coin or the fly.

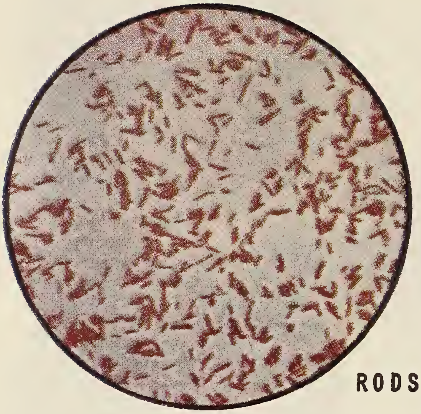
Set these dishes in a warm, dark place. Do not look at them for at least two days after you put them away. Then you will probably find that your dishes look like the pictures on this page. The fuzzy places on the food are molds. The smooth,

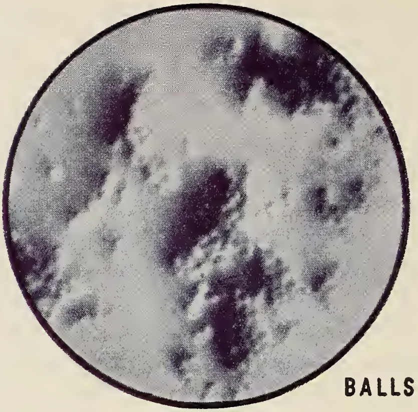

DROP OF WATER


FINGERS


LEFT UNCOVERED


KEPT SEALED





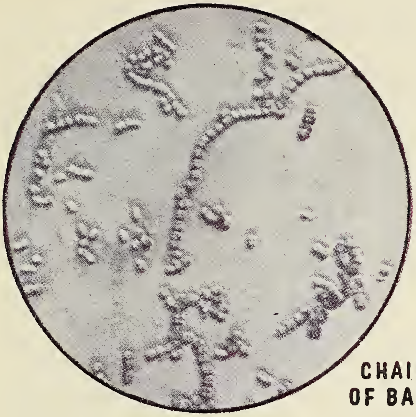
round, yellow or white spots in your dishes show where bacteria are growing. Do not touch these bacteria with your fingers.

If you lift the covers of the dishes, you will find that the dishes where bacteria are growing may have a very unpleasant smell. The bacteria are causing chemical changes in the food. They are changing the materials in the food into other materials. Some of these materials have a bad smell. You know that some of the things you use for food have bad smells when they spoil or decay. Bacteria are using these things for food and causing chemical changes in them, just as they change the food in your bacteria dishes.

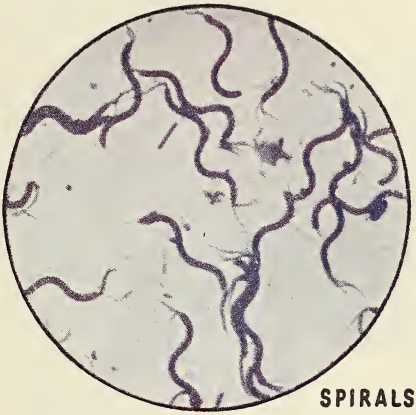
When germs get into your body, they make chemical changes take place. These chemical changes produce the materials that make you sick. Later in this unit, you will learn more about these materials.

If you can look at some bacteria through a microscope, you will see that they have different shapes. Some bacteria are tiny round balls like the ones in the picture. Some are spiral like a corkscrew, and others look like rods. But whatever shape they have, the bacteria are all alike in one way. Each of these bacteria is just one cell. You know that cells are the tiny blocks from which all living things are made. Your own body is made up of billions of cells, but each of these bacteria is only one cell. Some of them are so tiny that it would take thousands of them to cover the period at the end of this sentence. One spot in your dish contains millions of bacteria.

Bacteria have a very simple way of making more bacteria like themselves. They multiply by dividing! Each tiny plant divides into two smaller plants. These soon grow to full size, and then each one divides again. All this happens very quickly.



CHAINS OF BALLS



SPIRALS

One of the bacteria may grow and split into two parts in less than half an hour. Suppose that you figure out how many bacteria there would be in twelve hours if each one grew and divided every half hour. The table below will show you how to start.

Hours	*Bacteria*
½	2
1	4
1½	8
2	16
2½	32
3	64
3½	128

In twelve hours, there would be millions of bacteria, as you can see. Millions of these one-celled plants are growing in the gardens that you made. Bacteria multiply so fast that billions of them are produced every twenty-four hours.

You know that there are some very tiny animals that cause diseases. What you have just learned about bacteria is also true of these animal germs. They multiply very fast. They cause chemical changes inside your body, too. The materials that are produced by these chemical changes can make you sick.

1. *Why did you have to heat the Petri dishes in a hot oven?*
2. *Why were the test tubes plugged with cotton wads and then heated?*
3. *Why was one of the dishes not planted?*
4. *How are all bacteria alike? How are they different?*
5. *How do bacteria make more plants like themselves?*
6. *Why should a doctor know about bacteria?*

How do germs get into your body?

Before germs can make you sick, they must get inside your body and grow. But how do germs get into your body? They cannot walk or fly. So they must get inside your body in other ways. There are several ways that they do this.

If you grew some bacteria, you found that bacteria were on the pencil, the fingers, and the coin. They were in the milk and air, too. Bacteria are on or in almost everything. Of course, not all of these bacteria are germs. But some of them are germs. Anything you touch may have germs on it.

You know that a cut or burn is dangerous because it makes a break in your skin. Even a scratch may be an open door for germs to get into your body. Germs are in the air, and they are on your skin and clothing. If there is any opening in your skin, germs can get into your body and begin to grow.

Coughing and sneezing spread germs. If a person does not cover his mouth and nose, the spray from a hard cough or sneeze may travel ten or fifteen feet. You may breathe germs in this spray into your body. Or you may eat some food that this spray has settled on. Colds, influenza, tuberculosis, and several other diseases are often spread by coughing and sneezing.

Some people have a bad habit of putting their fingers or pencils in their mouths. Or they bite their fingernails. Their fingers have touched things that probably have germs on them. These people help the germs get into their bodies. You do the same thing if you eat without first washing your hands thoroughly.

Germs escape from a sick person in anything that comes from his body. They are in the air he breathes out, in the saliva from his mouth, in the discharges from his nose, and in anything else that comes from his body. Things that a sick person has touched and dishes that he has used may have germs on them. Handling these things may spread germs. If you eat from the dishes before they have been properly cleaned, germs may get into your body.

Germs can get into your body when you have not even been near a sick person. Here is one way that this happens. Germs get into your body when you drink impure water. The germs that cause typhoid fever are often found in water. They get into the water from the body of some person who is sick with the disease. Before scientists discovered that typhoid germs can live in water, the disease was much more common than it is now.

Germs are also spread in impure milk. You know that you should drink at least one quart of milk every day because it is such a good food. It is a good food for germs, too. If cows and cow barns are dirty, germs get into

This cabinet has a special kind of light that will kill any germs on the glasses.

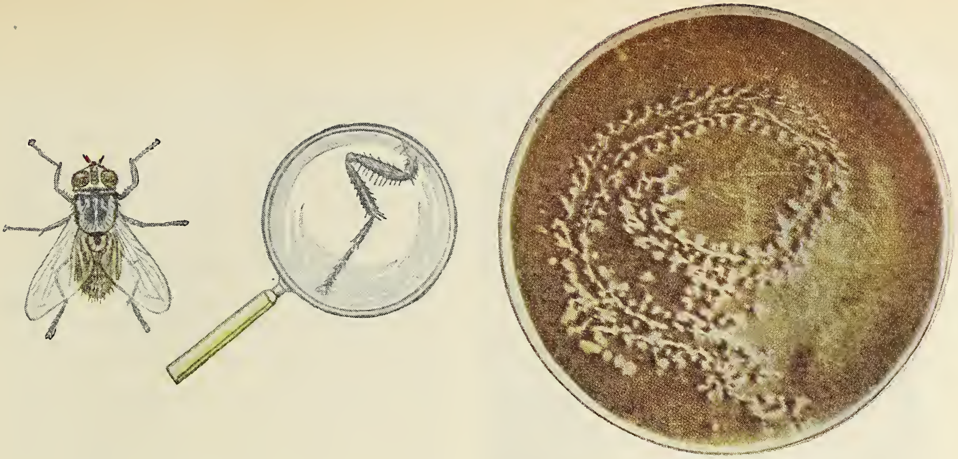
the milk that people drink. Dirty milk cans and bottles may also have germs in them.

Sometimes the cows or the people who milk them are sick. If a person with tuberculosis handles milk, the milk may have the germs in it. Cows can get tuberculosis, just as people do. Milk from these cows always has tuberculosis germs in it. Typhoid fever, diphtheria, and scarlet fever are other diseases that are spread in impure milk.

Other foods besides milk may spread germs. If you eat meat from a sick animal, you may get the same disease the animal had. Fruits, vegetables, and other foods from dirty stores may have germs on them. Do you know one way that germs often get on food?

If a fly walked on one of the dishes you planted, you found bacteria growing where its feet had touched the food. Look at a fly with a magnifying glass. You can see thousands of tiny hairs on its legs. Germs and dirt that stick to these hairs are carried far and wide.

Flies lay their eggs and get their food in dirty places. They often live in garbage, manure, and rubbish. Germs live there, too. Flies get the germs on their legs. Then they go into homes and stores, and they light on food with their load of germs. The germs have only a short trip to make when we eat the food. They are soon inside our bodies. Because flies often carry typhoid germs, they are sometimes called typhoid flies. Flies also spread tuberculosis.



A fly walked around on this Petri dish. Can you see how its legs can carry enough bacteria to make a trail like this?

Germs often "hitchhike" on other insects besides flies. One kind of mosquito carries malaria germs, and another kind carries the germs of yellow fever. The mosquitoes pick up the germs when they bite a sick person and suck his blood. If one of these mosquitoes bites a well person, some of the germs go into his blood. Then he gets sick with the disease. To keep malaria from spreading, we must kill these mosquitoes.

Lice and fleas also spread germs. They bite a sick person or animal and suck the blood. This blood has germs in it. When they bite a well person, the germs get into his blood and give him the disease. Rats and mice carry the lice and fleas from one place to another. When people are dirty and crowded together, the lice and fleas often get on their skins and into their hair. The deadly disease called typhus is spread in this way.

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1. *How do germs get into your body? Give as many different ways as you can.*
2. *Why is it not safe to drink from a cup or glass that another person has just used?*
3. *You should cover your mouth and nose with a handkerchief when you cough or sneeze. Why?*
4. *Look at the pictures on pages 104 and 105. Which pictures show ways of keeping germs from getting into your body? Explain your answer.*
5. *Why should you always wash your hands before eating?*

How does your body fight germs?

It is always best to cover a cut or a scratch as soon as you can.

PERHAPS YOU ARE wondering why you are not sick most of the time. There are so many different kinds of germs, and they seem to be in or on nearly everything. You may think that your body has not much chance of staying well. But your body has ways of keeping germs out. It can also fight them after they get in.

The skin that covers you from head to toe keeps many germs from ever getting inside your body. As long as there are no breaks in your skin, germs cannot get through it. That is why you should try not to cut or burn yourself. If you do get a cut or burn, take care of it at once. Wash off any dirt and cover the broken skin with a clean bandage. You should take a warm bath or shower at least twice a week to keep your skin clean.

The air you breathe has germs in it. Some of them are on the bits of dust that come in with the air. But your body has ways of keeping many of these germs out. Hundreds of tiny hairs in your nose stop some of the germs. Other germs are caught in a sticky liquid in your nose. You force these germs out of your body when you blow your nose. Be sure to blow your nose gently, or you may force the germs up into your ears. Coughing and sneezing also get germs out of your body.

In spite of everything that your body does to keep them out, some germs do get inside. Where do they go after they get in? That depends on what kind of germs they are. Germs go where they can live and grow best. Some kinds can live only in certain parts of your body. Pneumonia germs live best in your lungs. Tuberculosis germs can live in your lungs and some other parts of your body. Some kinds of germs grow best in your throat. Other kinds grow in your blood, bones, muscles, or nerves. Some kinds grow almost anywhere in your body.

When the germs get to a place where they can grow, they begin to divide and multiply. You know that this happens very fast. Some kinds of bacteria can grow to full size and divide in twenty minutes. But germs cannot grow without food. They use the materials in your body for food. Germs must live where they can get the kind of food they need. That is why some kinds of germs can live only in certain parts of your body.

After germs have multiplied in your body for some time, you begin to know that they are there. Germs make poisons as they grow and divide in your body. These poisons are called *toxins*. They may make some part of your body sore and red. This happens when you have a boil. The toxins may get into your blood and then be carried all through your body. You may have a headache, a fever, and sore, red eyes. Your body is out of order. Germs are using the materials in your body for food. They are making toxins and pouring them into your blood.

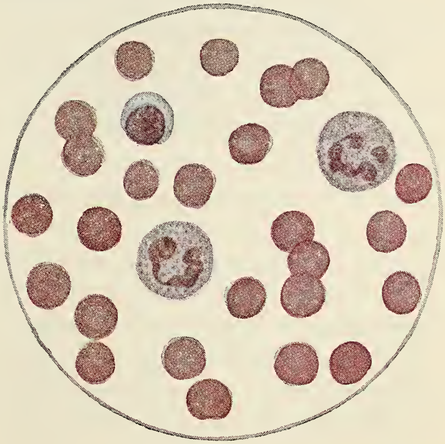
Your body fights back with its own weapons. Do you know what they are? In your blood, there are white cells. The white cells are also called white *corpuscles*. Corpuscle means little body. The white corpuscles are powerful enemies of germs. You know that blood flows to every part of your body. So these germ fighters go everywhere in your body, too.

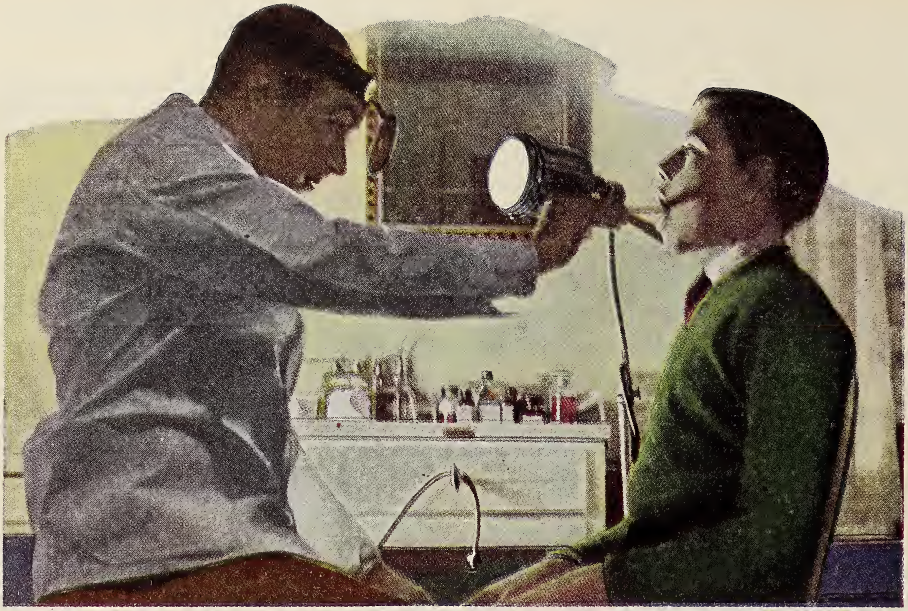
Whenever germs get inside your body, the white corpuscles gather at the place where the germs are. The white corpuscles are so small that they can pass out of the blood vessels and into the cells. When they get to the germs, the battle begins. The white corpuscles kill the germs by eating them.

If your body is well and strong, it will usually have enough white corpuscles to kill the germs. These white cells in your blood have often kept you from getting sick, because they killed the germs quickly. But sometimes germs multiply so fast that the white corpuscles cannot fight them successfully. Then the germs make you sick.

There is still another way that your body fights germs. Certain cells in your body make materials that are poured into your blood. Some of these materials make germs more appetizing to the white corpuscles. They are somewhat like the sugar and cream you put on breakfast food to make it taste better. Some of these materials kill germs. Others change the toxins and make them harmless. The mate-

These are blood cells. The three largest cells are white corpuscles.





rials that do this are called *antitoxins*. Anti- means against, and toxin means poison. Your body makes all of these germ fighters more easily if it is healthy. So you see another important reason for building a strong body.

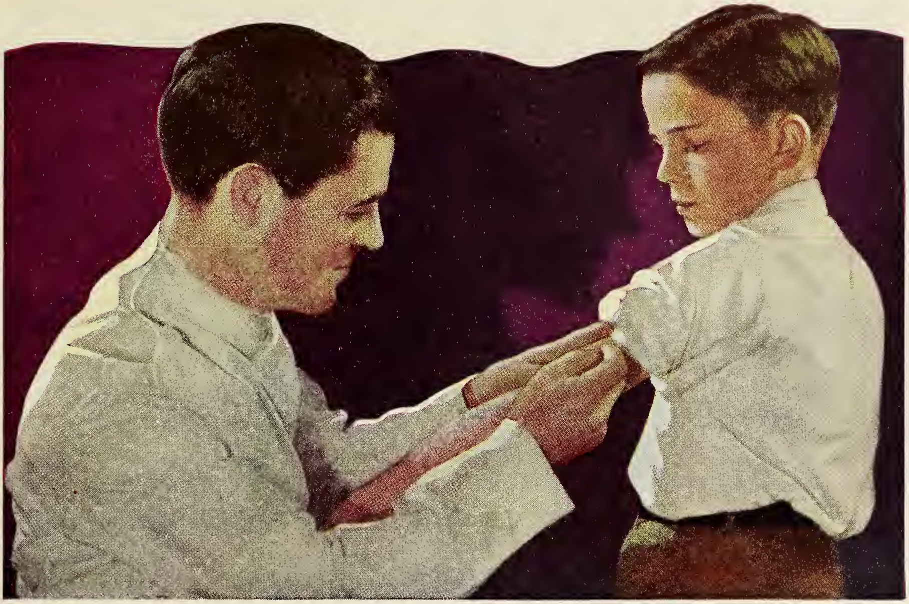
---

1. *How does your body keep some germs from getting inside?*
2. *Why do germs make you sick?*
3. *How does your body fight germs that get inside?*
4. *What is a* toxin? *What is an* antitoxin? *Which one does your body make? Which one do germs make?*

How do scientists help your body fight germs?

NOT MANY YEARS AGO, smallpox was a very common disease. Thousands of people died from it every year. Those who got it and lived were left with ugly marks on their bodies. Today, smallpox is no longer a common disease. Scientists know how to keep us from getting it. Do you know what they do to help our bodies fight this disease?

Almost every boy and girl in your school has been *vaccinated* against

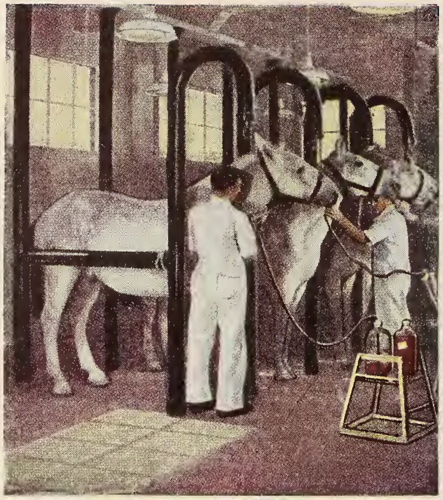


smallpox. When you are vaccinated, a doctor puts a liquid into your body. This liquid is called a *vaccine*. It is put into your body to keep you from getting the disease. The vaccine makes your body produce antitoxins. If smallpox germs get into your body, the antitoxins will make the toxins that the germs produce harmless. Then the white corpuscles in your blood will have time to kill the germs before they can multiply very much.

The antitoxins stay in your body for about seven years. During this time, they protect you from smallpox. After seven years, you should be vaccinated again. You can also be vaccinated against typhoid fever, influenza, and several other diseases. A short time before American and British soldiers went into Italy, a vaccine for typhus was discovered. In other wars, more soldiers were killed by typhus than were killed by bullets. But this time not one soldier died from the disease. The vaccine saved thousands of lives.

Scientists have another way of helping your body fight germs. They use another kind of liquid to do this. This liquid is called a *serum*. It contains antitoxins that make the toxins produced by germs harmless. When the serum is put into your body, the antitoxins are ready to help the white corpuscles fight germs.

Serums are made in a very interesting way. To make the serum for diph-



Blood from these horses will give antitoxins.

theria, scientists put some of the toxins made by diphtheria germs into a horse. The body of the horse makes antitoxins and pours them into the blood. Then some of this blood is taken from the horse. The serum that is made from the horse's blood has the antitoxins in it.

Serums and vaccines keep you from getting certain diseases. Scientists have also discovered materials that will cure certain diseases after you get them. You have probably heard about the "sulfa" drugs. They are some of our best germ killers. They have cut the deaths from some diseases to less than one third of what they used to be.

The first sulfa drug was made about forty years ago. But for a long time, no one knew that it would help kill germs. Then a little over ten years ago, a scientist discovered that it would cure certain diseases caused by bacteria. Some of these diseases, such as pneumonia, killed thousands of people every year. Since that time, other scientists have made many different sulfa drugs. Each kind is best for a certain disease. When bacteria take a sulfa drug into their bodies, they stop growing and do not divide. Then the white corpuscles kill the bacteria.

An even newer drug works better than the sulfa drugs in curing some diseases. This drug is called penicillin. It is produced by a green mold plant. Penicillin kills germs in about the same way that sulfa drugs do, but it is less dangerous for a person to take. Remember that penicillin and the sulfa drugs are new discoveries. Scientists still have a great deal to learn about using them. Never take any of these drugs unless a doctor tells you to.

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1. *What is a* vaccine? *How does it help your body fight germs?*
2. *What is a* serum? *How does it help your body fight germs?*
3. *Thousands of people who might have died during the last ten years are alive today. Why do you think this is true?*

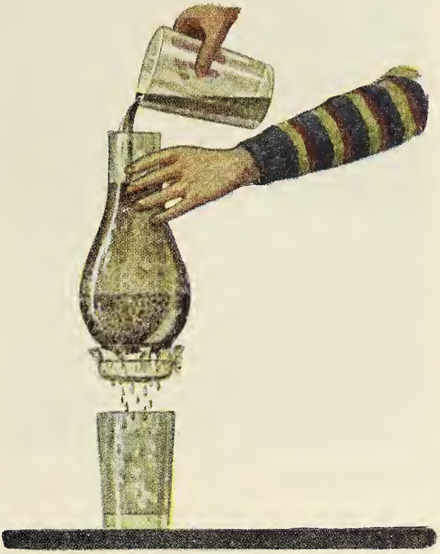
How can we keep germs from spreading?

YOUR BODY FIGHTS germs, and scientists have discovered many ways to help it fight them. But there is a better way to control germs. Do you know what it is? Stop and think how germs get into your body. If we keep germs from spreading, we can prevent them from making people sick.

A town once used this sign to advertise itself to travelers. "Millville is the most *sanitary* town in this state." Sanitary means clean and free from germs. If you were planning to make your town a very sanitary place to live, what would you do?

First, you probably would think of all the ways that germs are spread. Then you would try to think of ways to keep them from spreading. You know that water, milk, and food can spread germs if they are not kept clean and pure. What can we do to keep water, milk, and food free from germs?

The water you drink may come from a lake, a river, or a well. Suppose that it comes from a very muddy river. Animals have lived and died in the water of the river, and their bodies have decayed in it. Dirt gets into the river from all along the river banks. If there are towns on the river, germs from sick people probably get into the water. How can this dirty water that is full of germs be made pure and safe for drinking?



You can find one way to make the water pure by doing an experiment. Tie a cloth over the bottom of a lamp chimney or fasten it with a rubber band. Pour some coarse gravel into the chimney until you have a layer about three inches deep. Then put in sand until it is about two inches from the top. Hold the lamp chimney over an empty glass. Then pour a glass of muddy water into the chimney. Look at the water that comes through the sand and gravel into the glass below. Then pour this water into the chimney again and let it run through into the glass. Is the water in the glass clear now?

This way of taking dirt out of water is called *filtering*. Do not drink the

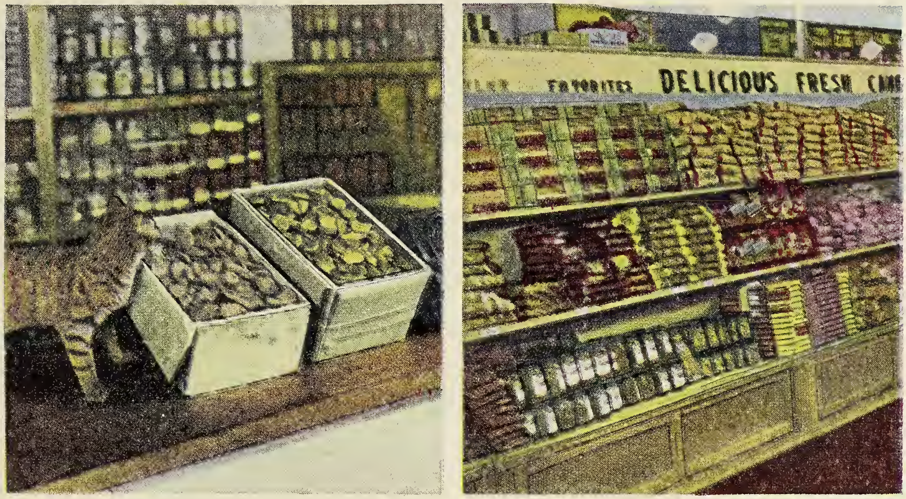
The water is being sprayed into the air so that sunshine and the oxygen in the air can help purify it.

water you have filtered. It may not be pure even though it looks clear. When water is filtered for a town or city, it runs through much more sand and gravel than you used. In the filtering plant of a city, there are big, deep layers of sand and gravel that take dirt and some germs out of the water. Of course, the sand and gravel have to be cleaned now and then.

Another way to make water pure is to spray it into the air. Germs do not live well in sunshine and fresh air. When water is sprayed into the air, sunlight and oxygen kill many of the germs. Still another way to make water pure is to add chemicals that kill germs. A gas called chlorine is often used. A very small amount of chlorine will kill the germs in thousands of gallons of water. Many cities use filtering, spraying, and chemicals to get pure water. The water is tested every day, or several times a day, to make sure that the germs have been taken out or killed.

Water can also be made pure by boiling it. You can use this way in your home. But, of course, a city could not boil all the water that its people use. Many times when something goes wrong with the water supply in a city or town, the people will be warned to boil all the water they drink. You can see that a supply of pure water is one of the things that make a town sanitary.

Have you ever visited a dairy farm? If the farm supplies milk that is safe to drink, you will see a clean barn with clean cows, clean workers, and clean milk cans. The farmer will be



Which store do you think it would be safer to buy food from? Why do you think so?

sure that the cows are healthy. The cows will be tested to see if they have tuberculosis or any other dangerous disease. Any cows that are not healthy will be killed. If the milk goes to a dairy to be put into bottles, the dairy should be clean, too. In your sanitary town, you would not let a farm or dairy sell milk unless health officers found that the milk was clean.

To keep milk safe, dairies pasteurize it. Louis Pasteur discovered this way to keep milk pure. Milk is pasteurized by heating it to 145°F. and keeping it at that temperature for half an hour. Many cities do not allow milk to be sold unless it has been pasteurized.

What would you do about stores, restaurants, and other places that sell food in your sanitary town? Health officers should see that the stores and restaurants are kept clean. The people who work in them should be clean, too. Meat, vegetables, fruits, and other foods that spoil easily should be kept cool in a *refrigerator*. Flies, rats, and other animals should be kept away from the food. Every restaurant should have a clean kitchen with clean food. To kill germs, the dishes should be washed in hot, soapy water and then rinsed in clear, boiling water. This will make the dishes safe to use.

Of course, every dirty place in the town should be cleaned up, too. This will help get rid of the flies and rats. Dirt and rubbish in the streets should be collected and burned. All garbage pails should be tightly covered. The garbage should be collected and then burned or buried. Oil should be put

This machine is spreading a kind of fog of DDT spray to see if it will kill the mosquitoes and other insects on the beach. Outdoors, the spray soon thins out and does not harm people.

on streams and ponds where mosquitoes lay their eggs. Wire screens on windows and doors will keep out both mosquitoes and flies.

A few years ago, scientists discovered an insect killer that is sure death to flies, mosquitoes, lice, and fleas. This insect killer is a white powder called DDT. It is usually mixed with other materials so that it will not be too strong. To control typhus in Naples, more than a million people were dusted with DDT. It killed the lice and fleas on their bodies. In the Pacific Ocean, airplanes sprayed DDT over entire islands to kill the mosquitoes that carry malaria germs.

DDT can be sprayed on screens or other places where flies and mosquitoes gather. It will kill insects for several months afterward. It does not kill them at once, but any fly or mosquito that touches it will soon die. If you use DDT around your home, be careful not to spray it on food or dishes. Do not breathe it into your lungs or swallow it. Remember that DDT is a poison.

In your sanitary town, something else should be done to keep germs from spreading. Whenever anyone gets a disease that can be easily carried from one person to another, he should be kept away from other people. If he has measles, mumps, chicken pox, whooping cough, diphtheria, scarlet fever, smallpox, or any disease like these, he should stay at home. A health officer should put a sign on the door. Then people can see the sign and know that they are not allowed to go in. We say that the sick person is *quarantined.* He cannot leave his home until a health officer takes the sign down.

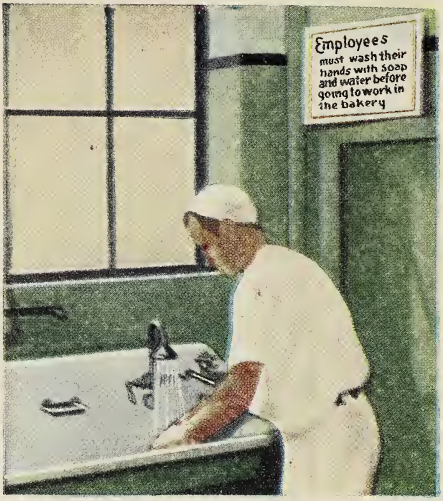
After the sick person is well again, his room and bedclothes should be cleaned thoroughly. All the germs should be killed. None should be left to spread the disease to someone else. A chemical called a *germicide* should be used. Germicide means germ killer. Sometimes the sick person's room or even his home must be *fumigated.* To do this, a germicide that is a gas is used. The gas goes into all the cracks and kills the germs.

The war against germs must be fought every hour of every day. Before people knew how to fight germs, terrible *epidemics* used to sweep through the towns and cities of the world. When a disease spreads so rapidly that many people have it at the same time, we say that there is an epidemic of the disease. During one epidemic in Europe, at least 25 million people died. In some parts of the world, there are still terrible epidemics. But in our country and many others, thousands of doctors, nurses, health officers, and other scientists are fighting the war against germs. They save us from the terrible epidemics that killed so many people in the past

Dishes that a sick person has used can be made safe by boiling them for a minute or two.

---

1. *What is done in your community to keep germs from spreading?*
2. *How is the milk you drink made safe?*
3. *What is done in your school to keep germs from spreading?*
4. *In your own words, tell what* quarantine *means.*
5. *Make a list of rules for keeping your community sanitary. Give a reason for each rule.*
6. *How is the water you drink made pure?*
7. *How can we control insects that spread disease?*


Employees must wash their hands with soap and water before going to work in the bakery

What does the sign in the picture on the left mean when it says "Safe Water"? This man is working in a bakery. Why should he always be careful to obey the sign on the wall?

QUESTIONS TO ANSWER

1. How did the invention of the microscope help scientists discover germs?

2. Why does the health officer quarantine people for some diseases but not for others?

3. Read over the directions for growing bacteria on pages 100 and 101. Suppose that you found bacteria growing in Dish 6. What would this tell you about how you did the experiment? Why?

4. Two important discoveries helped doctors stop the spread of typhus. Tell what each discovery was and what it did to stop the disease.

5. If you were not sure that some water was pure, what could you do to make it safe to drink? How can milk be made safe?

6. Make a list of rules that will help you keep from getting sick.

7. What should you do if you do get a disease?

8. Explain why a strong, healthy body is your best protection against disease.

9. What can you do to keep your body strong and healthy?

10. How can you keep from spreading germs to other people?

11. How are vaccines and serums alike? How are they different?

12. What is one way in which animals are used to help keep us well? Explain your answer.

13. Diseases are often spread in trains, buses, motion picture theaters, and other crowded places. Explain how this happens.

THINGS TO DO

1. Find out how often the water you drink is tested to make sure that it is pure.

2. Read about Edward Jenner and vaccination against smallpox.

3. Visit a dairy to see how milk is kept free from germs.

4. Mosquitoes once stopped the building of the Panama Canal. Find out what was done to control them.

5. Animals and plants have diseases. Find out what some of the diseases are and how they are caused.

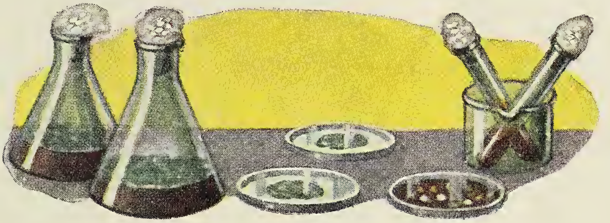
6. Read about Sir Alexander Fleming and the discovery of penicillin. Make a report to your class.

7. Find out what diseases are carried by animals and which animals carry them.

8. Learn more about the sulfa drugs. Find out for what diseases each drug is best.

9. Read about some of the epidemics that killed millions of people in Europe and Asia.

10. Take a walk around your community to see whether it is sanitary. Be sure to visit food stores and restaurants. Find out how the people in your community work together to make it a healthful place. Then make a report to your class.



★ *In Unit Five You Will Learn* ★

★ Where electric current comes from ★ How we connect electric appliances ★
★ Why electric wires are covered ★ How we protect buildings from short circuits ★
★ How we control electric current ★ How we use electric current to make heat ★
★ How electric current gives light ★ How we use electric current to make a magnet ★
★ How a telegraph works ★ How an electric bell rings ★
★ How an electric motor runs ★

★ UNIT 5 ★

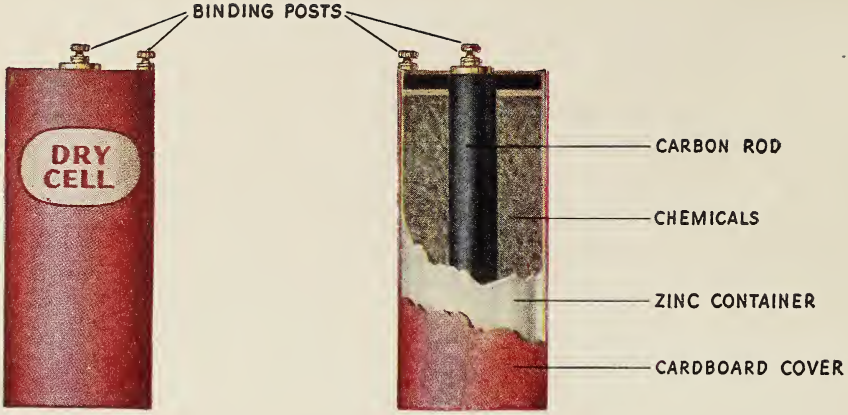
How Do We Use Electric Current?

One winter evening, there was a terrible storm. Snow and ice began to gather on the wires that carried electric current from the powerhouse to the city. At last, the load of snow and ice became so heavy that some of the wires snapped. In an instant, the city was in darkness. Just a moment before, the streets, homes, and stores had been brightly lighted.

Of course, some electric current was still being used. Flashlight batteries supplied enough current to make some light. Automobile batteries provided current to start the cars and light their lamps. In a hospital, a doctor was performing an operation when the lights went out. Quickly the storage batteries were switched on. These storage batteries were kept for just such an emergency. But everything that used electric current from the powerhouse had stopped working.

In the theaters, there was no current to run the moving-picture machines. A dentist had to stop filling a man's tooth, because there was no current to turn his drill. In the newspaper office, the printing presses stopped running. So the newspaper for the next morning could not be printed.

Out in the country, some farms used electric current from the same powerhouse. Now there was no current to light the homes and barns or to run the pumps that brought water up from the wells. In almost every home and building in the city and on the farms nearby, there were tools and appliances that would not work because the current was off. You can see that it was a serious thing to have the electric current go off. In this unit, you will learn how electric current does many useful and important things for you every day.



Where does electric current come from?

YOU CAN EASILY learn about one way that we use to make electric current. Get an old, worn-out dry cell and break it open to see what it is made of. First, pull off the cardboard cover and notice the metal underneath. This metal is zinc. Now break off the top of the dry cell and pour out about half of the black mixture inside. You can see a black rod in the center. This rod is made of carbon.

Look at the black mixture that you have poured out. There are some chemicals in it. Different chemicals are used in different kinds of dry cells. But all dry cells have a zinc container for the chemicals and the carbon rod. If you feel the chemicals, you will find that they are moist. So a dry cell is not really dry except on the outside. The top is sealed to keep the chemicals moist. The zinc container also helps keep them from drying out.

If you look carefully at the worn-out dry cell, you may find some holes in the zinc. You may also find some white powder on it. What do you suppose made the holes and the white powder? You know that materials can change into other kinds of materials. When they do this, we say that a chemical change takes place. This kind of change goes on in a dry cell. The chemicals inside the cell change part of the hard zinc into a soft, white powder. When this chemical change happens, the cell makes an electric current.

After the cell has been used for a time, the chemical change stops. When this happens, the cell can no longer make an electric current. So we say that the cell is dead. Cells can become dead even if they are not used. When they stand for a long time, the chemicals become dry or they slowly change. Then the cell cannot make current.

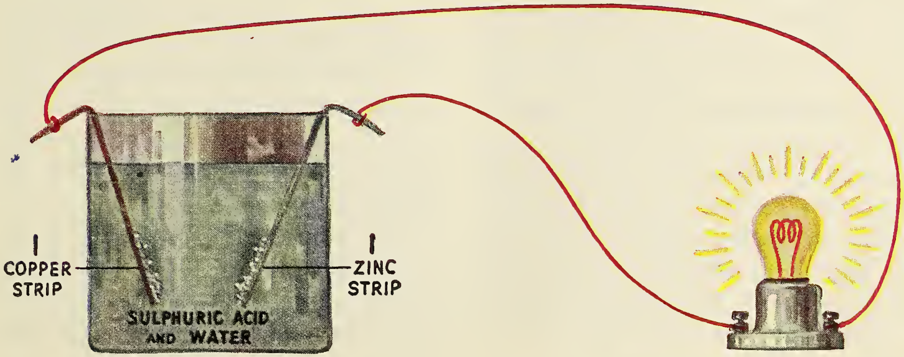
Look around to see how many places you can find where dry cells are used. You will probably find two or more cells connected together to form a battery. As you might expect, a battery of cells can supply more current than just one cell. A flashlight usually has a battery of two or more cells inside its case.

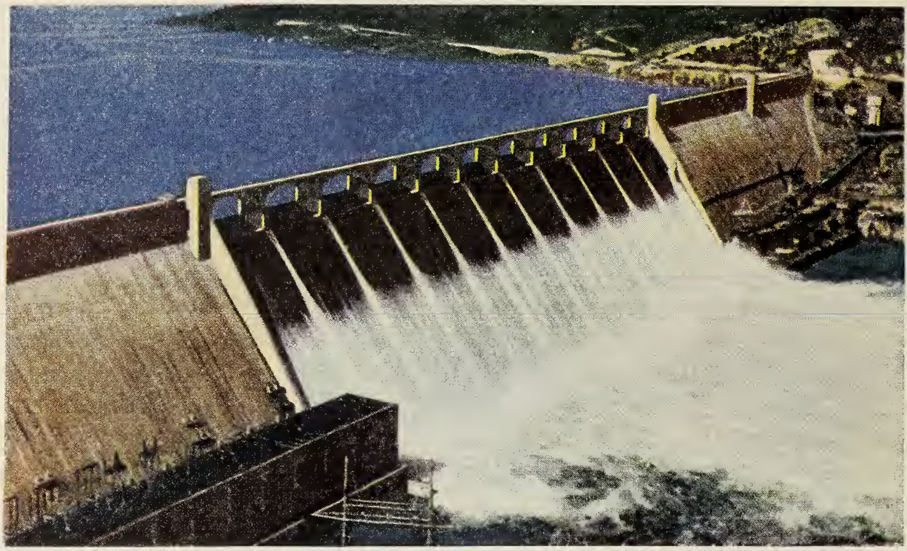
Besides a dry cell, there is another kind of electric cell that makes current. This kind is called a wet cell. Perhaps you can make a wet cell right in your classroom. Then you can use it to light a small electric bulb. Get a drinking glass or a small glass jar. Also get a strip of zinc and a strip of copper. Each strip should be about one inch wide and five inches long. The wider the strips are, the better the cell will work. Punch a hole in one end of each strip. Then bend the strips so that they will hang from the rim of the glass, as shown in the picture below.

Now get two or three feet of covered copper wire. Cut the wire into two pieces of the same length. Scrape about an inch of the covering off both ends of each piece of wire. Put one end of a wire through the hole in one of the metal strips. Fasten the wire tightly to the strip. Do the same thing with the other wire and the other strip.

The cell is now ready to put together. Have your teacher fill the glass about three-quarters full of a mixture of sulphuric acid and water. The mixture should be about one part acid and ten parts water. Hang the metal strips in the mixture of acid and water. Be careful not to let the strips touch each other. Screw a small electric-light bulb into a socket. Connect the wires to the socket. Does the bulb light up? If you have a small electric bell, connect it to the cell in place of the bulb. Does the bell ring?

If the metal strips are big enough, the lamp should light or the bell should ring for a short time. Do you





Grand Coulee Dam in the state of Washington is one of our largest dams.

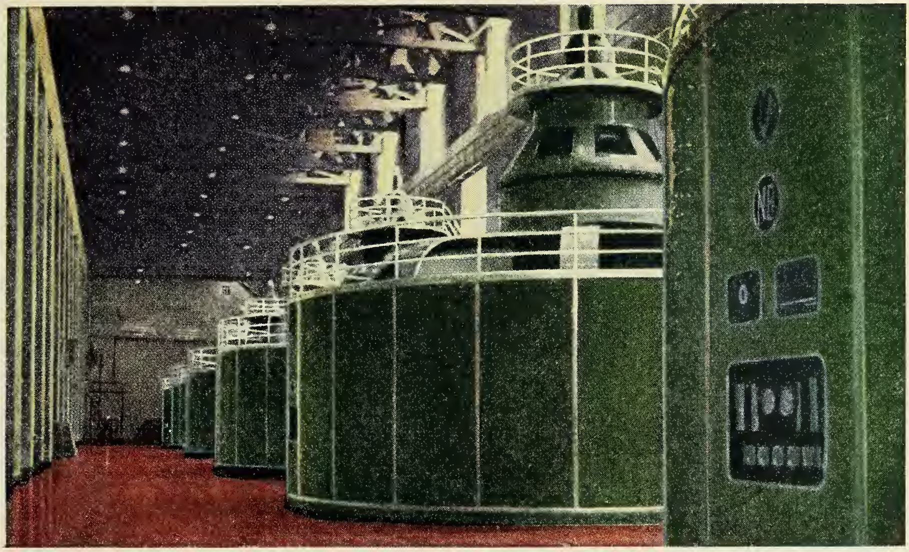
see bubbles gathering on the metal strips? These bubbles show that a chemical change is taking place in the acid and on the metal strips. This chemical change makes an electric current.

In an automobile, there is a battery of wet cells to supply electric current. This battery is called a storage battery. It is usually made of three wet cells connected together. These cells are very different from dry cells. If the cells in a storage battery become dead, they can be *charged.* Then they will supply electric current again. To charge a storage battery, an electric current from some other source of current is run through the cells for a while.

Electric cells do not supply the huge amounts of current that we use in our homes and other buildings. You know that wires come into our buildings from outside. We have to pay for the electric current that we get in this way. Where does this current come from?

If you could follow the wires that bring current into your home, you would find that they lead to a powerhouse. Inside the powerhouse, you would see some machines that make electric current. These machines are called generators.

You would hear a humming sound in the powerhouse, too. This sound comes from the generators. They are whirling around very fast as they



These are the huge generators in the powerhouse at Hoover Dam on the Colorado River.

make electric current. You know that it takes a force to make anything move. You also know that some kind of energy is needed to produce a force. Let us find out what kinds of energy produce the force that makes a generator turn at high speed.

Each generator in the powerhouse is connected to a *turbine*. This is a wheel that has slanting blades. When something strikes the blades, the turbine whirls around like a pinwheel. If the powerhouse is near a dam or waterfall, swiftly moving water rushes through the turbine and makes the generator turn very fast. The energy of moving water produces the force that makes the generator move around.

Huge amounts of electric current are produced by the energy of moving water. This current can be sent through wires to places hundreds of miles away. You may have seen the tall steel towers that hold up the wires. Electric current used in Los Angeles comes from a powerhouse in the mountains 250 miles from the city. The powerhouse is near a big dam built across a river.

Large waterfalls are sources of energy, too. There is a powerhouse at Niagara Falls. Part of the water at Niagara Falls is sent through turbines that turn very large generators. The electric current made by these huge generators is sent through the wires to cities that are many miles away.

Many places in our country have no swiftly moving water to use in making electric current. So something else must be used to turn the generators. Often they are run by the energy of steam. Coal, oil, or some other fuel is burned to produce the heat that changes water to steam. Then the steam shoots with great force against the blades of a turbine. As the turbine whirls at high speed, it makes a generator turn. The energy of steam produces the force that runs the generator.

Besides the energy of steam or moving water, other forms of energy can be used to turn a generator. The energy of moving air, or wind, is often used to make electric current on farms. The wind turns a windmill that is connected to a generator.

Another form of energy used to make electric current is the energy of exploding gas. When gas explodes in a gasoline engine or a Diesel engine, it can push with great force. This force will turn a generator and make electric current. The gasoline engine of an automobile runs a small generator in the car. This generator helps keep the storage battery charged. It also produces current for the car to use while the engine is running.

You have learned that we get electric current in two ways. Some of the current we use comes from cells, but most of it comes from generators. You know that different forms of energy are used to make electric current. The energy that cells use to make current is stored in the materials from which the cells are made. When a chemical change takes place, the energy stored in the materials is changed to electric current. Generators change the energy of moving water, steam, wind, and exploding gas into electric current.

Scientists know that an electric current has energy. It can produce a force that will make things move, and it can do much useful work. The energy of an electric current comes from other forms of energy. Cells and generators change these forms of energy into electric current.

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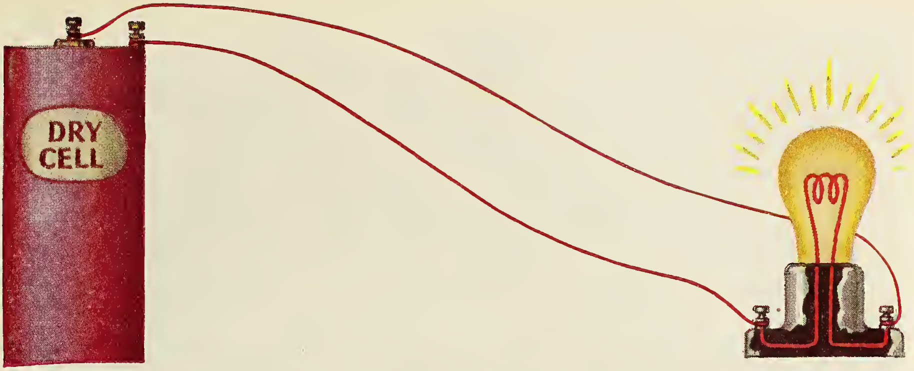
1. *What must happen in an electric cell before it will make a current?*
2. *Why do dry cells become dead?*
3. *If you are talking about just one dry cell, why is it not correct to call it a battery?*
4. *How are dry cells different from storage batteries?*
5. *Name four forms of energy used to turn generators that make electric current. Tell how each form of energy is used to do this.*
6. *Where does most of the electric current used in your home or school come from?*



How do we connect electrical appliances?

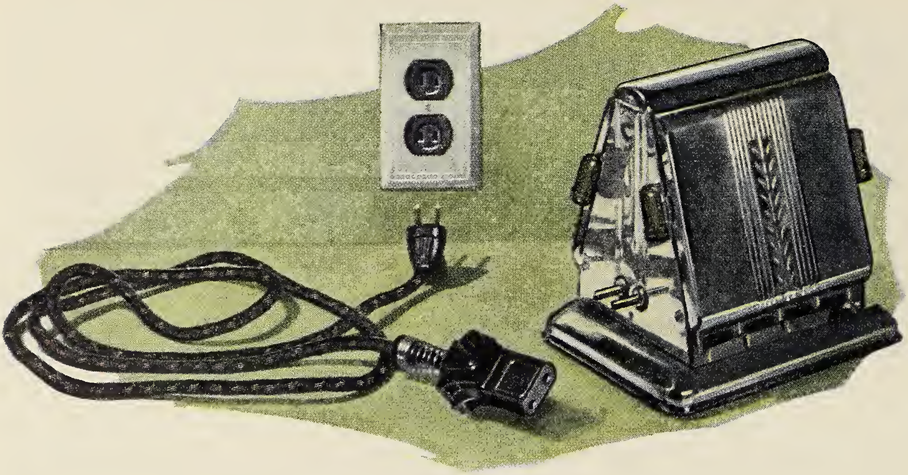
THE ELECTRIC CURRENT that you use in your home may come from generators nearby or far away. But no matter where it comes from, the current has to be brought to your home. Then it must be made to go to light bulbs, toasters, irons, radios, and other electrical appliances. How do we make the current go where we want it to go?

An experiment will help you find out. Get two short pieces of covered copper wire. Scrape the covering off the ends as you did before. Screw a small light bulb into a socket. Connect one wire from the socket to a *binding post* of a dry cell. Does the bulb light? Then connect the other wire from the socket to the other binding post of the cell. Does the bulb light now? Why?

Study the wires carefully. See if you can trace the current as it flows along. Start at one binding post of the dry cell. Follow the wire to the socket. Notice that there is a wire in the bulb. Then follow the other wire from the socket back to the dry cell.

If an electric current made a red line as it flowed, your wires and bulb would look like those in the picture. Trace the red line from the dry cell through the bulb and back to the cell. Do you see that the current flows back to the place where it starts? The path that the current follows is called a *circuit*. The current will not go just part of the way around this circuit. If it cannot travel all the way, it will not flow at all.

A current will not flow unless the circuit is *closed*. If a piece of wire is missing from the path, there will be a break in the circuit. Then the circuit will be *open*, and no current will flow. If you disconnect one end of a wire leading to the bulb, the light goes out at once. Hold the end of the wire near but not touching the place where it was connected. Does the bulb light?



The bulb will not light unless the end of the wire touches the place where it was connected. Small as it is, this break in the circuit keeps the current from flowing. A circuit must be closed before current will flow through it.

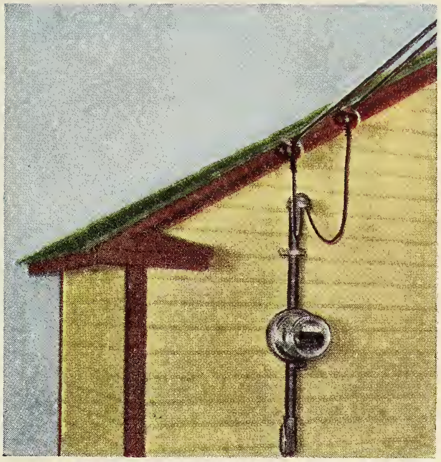
Look at the cord of an electric iron. You will find that the cord is made of two wires twisted together. On one end of the cord is a plug with two prongs. Each prong is connected to one of the wires in the cord. At the other end of the cord is a socket that fits tightly over two prongs on the iron. When the cord is connected from the iron to an outlet where current comes into the room, the current goes into the iron through one wire and out through the other.

Now look at the cord that you use with an electric toaster. Does it have two wires? Does the plug have two prongs? In all electrical appliances that you use, there are two wires to make a closed circuit for the current.

You know how the electric current gets to your home. Gas and water are brought to your home in pipes. But current comes to your home through wires from the powerhouse where it is made. Can you find the place where the current comes into your home? Notice that there are at least two wires.

In the picture on the next page, two wires bring the electric current to the house from the main line. Sometimes there are three and sometimes you see only one. When you see only one wire, it is because several wires have been put together inside one covering. You know why there cannot be just one wire. It is because there must always be a closed circuit for the current to flow through.

When you are using toasters, fans, irons, radios, and other electrical appliances, remember that the current is not the small current from a dry cell. You are using a current that is dangerously strong. Be sure to handle this current safely. The current is a good helper. But if you handle it carelessly, it can burn you or even kill you. Many people are burned or killed every year because they do not handle electric current carefully. Here are some good rules for you to follow when you use electrical appliances or play with electrical toys.



These wires bring current into the house.

Safety rules for using electrical appliances

1. Disconnect all electrical appliances when they are not being used.
2. If there is a switch on an electrical appliance, turn it off before you disconnect the appliance. Also be sure the switch is turned off before you connect the appliance.
3. Never use an electrical appliance or an electric cord that you know is out of order.
4. Never try an experiment with an electrical appliance or an electric cord that is connected to the current in your home.
5. Never touch an electrical appliance with wet hands. Also be sure not to touch it if any part of your body is against a water pipe, faucet, or radiator.

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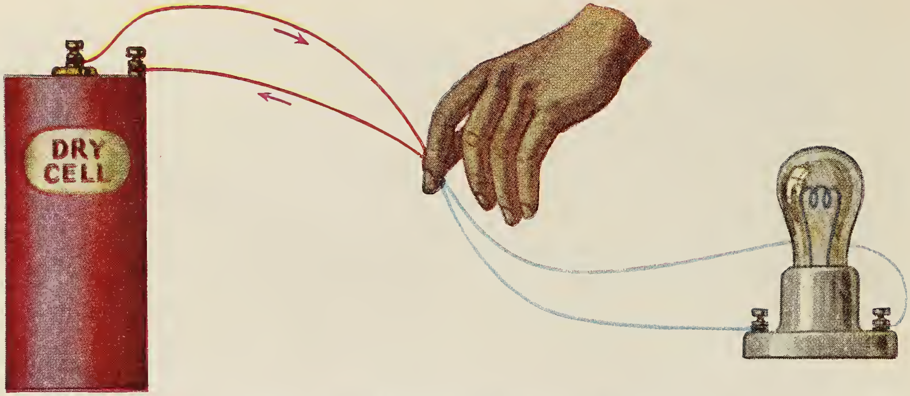
1. *What is a* closed *circuit? What is an* open *circuit?*
2. *What happens if a circuit is broken in any place?*
3. *Explain how an electric current travels through an electric iron or toaster.*
4. *Does the current that you use in your home travel through a closed circuit? Why do you think so?*
5. *Why do you think you should obey the safety rules for using electrical appliances?*



Why are electric wires covered?

PROBABLY YOU HAVE noticed that nearly all the electric wires we use are covered. In your experiments, you had to scrape off some of the covering to connect the wires. If you looked at the cords of electrical appliances, you found that the wires inside were covered. The wires that bring electric current into your home are covered, too. Why do you think that all these wires are covered?

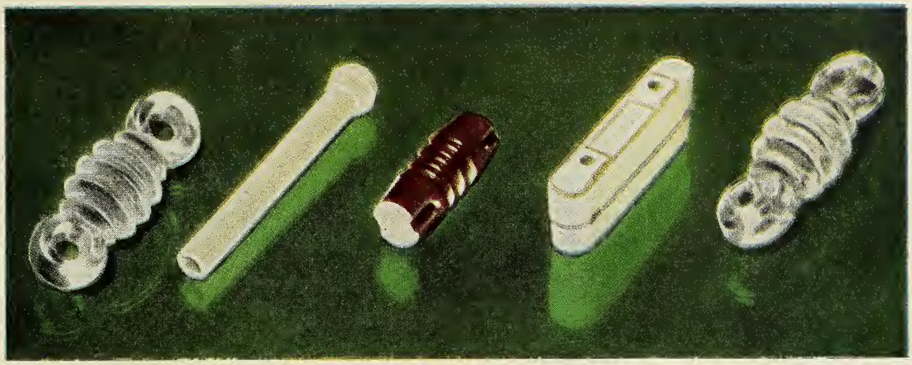
You can do an experiment that will help you answer this question. Connect a small light bulb to a dry cell. Use bare wires. Then touch the wires together, as shown in the picture. Watch what happens. Do you know why the light goes out? Is current flowing through the wires to the bulb? Do you think current is flowing through these wires? Then separate the wires. Does the light go on again?

The current has taken a short cut. This short cut is called a *short circuit.* When two wires were touched together, they made a closed circuit. But this was a shorter circuit than the one through the bulb. At once, the current went through the shorter path.

The light went out because nearly all the current flowed from one wire to the other without going through the light bulb. As soon as you separated the wires, the current flowed around the circuit from the cell, through the bulb, and back to the cell. Then the light went on again.

Electric current would not be very useful if we could not make it go where we want it to go. The current would not do useful work for us if it always took a short cut back to where it started. We want to make it go where we can use it. So we make the current flow through a longer path.

If there is a short circuit in the wires in your home, the lights go out. A short circuit in the wires of an automobile may keep the engine from



running, or it may put the lights out. So we must try to prevent short circuits. Let us see one way that this is done.

You already know that nearly all electric wires are wrapped with a tight covering. If you look at some of these wires, you will find that the covering is made of cotton, silk, or rubber. Connect a small light bulb to a dry cell. This time use covered wires. Touch the wires together as you did before. Does the light go out or does it stay on?

This experiment shows you that electric current will not travel through the material that covers the wire. But it does flow through the copper in the wire. A material through which current will flow is called a *conductor*. Copper is a conductor of electric current. So are silver, aluminum, iron, and brass.

Any material through which electric current will not flow is called a *non-conductor*. It is also called an *insulator*. Cotton, silk, and rubber are non-conductors, or insulators. Wire that is covered with an insulator is called *insulated* wire. Enamel is an insulator. So wire is sometimes insulated with a coating of enamel. Glass and porcelain are also insulators. They are used to support electric wires on poles.

The experiment shows you one way to prevent short circuits. You use insulated wires. Then even if the wires do touch each other, the current will not flow from one wire to the other. The covering is an insulator. It keeps the conductors from touching each other.

Do you know why an electric current can be dangerous when it takes a short cut? Do the experiment with the bare wires again. When the bulb is lighted, feel the wires. Do they feel warm? Now touch the wires together near the dry cell. Hold your fingers near the wire where the current is still flowing. How does the wire feel this time? Be careful not to burn your fingers.

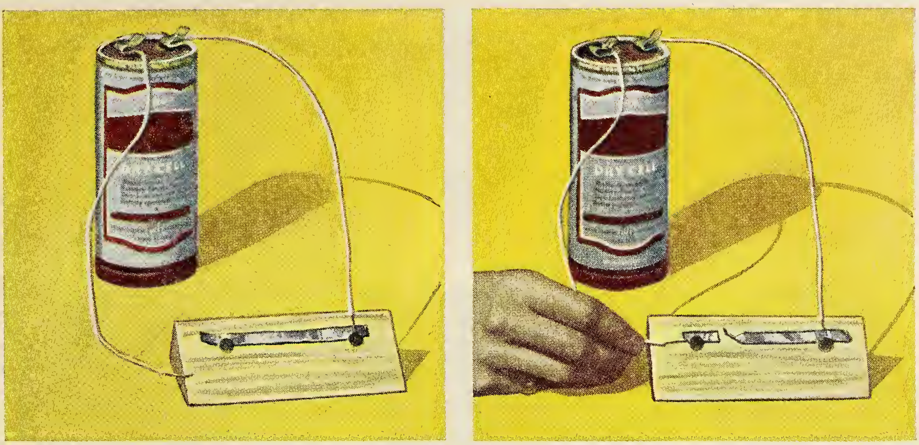
You can see from this experiment that a short circuit makes a wire get hot. The wires in your home would become very hot if the bare wires were allowed to touch each other. They might get so hot that they would set fire to something. Every year, many fires are caused by short circuits.

The danger of short circuits is not the only reason why wires are insulated. Have you ever had a shock from touching bare wires? Such a shock can be very serious. If you take hold of a bare wire through which a strong current is flowing, you will be badly burned. You may even be killed. So that is another reason why wires are insulated and why you must never touch bare wires.

Safety rules for using electric wires

1. Never touch electric wires or use an electric cord on which the covering is worn.
2. Keep electric wires and cords from rubbing against things or becoming kinked. Rubbing may wear off the covering, and kinking may break it.
3. Stay away from broken wires that hang down from poles or buildings.
4. Never climb a pole that supports electric wires.
5. Never touch an electric wire or cord with wet hands. Also do not take hold of a wire or cord while any part of your body is touching a water pipe, faucet, or radiator.

1. *Make a drawing to show what a short circuit is.*
2. *In most of your experiments with electric current, you use insulated wire. Why do you have to scrape some of the covering off the ends of the wire before you connect it?*
3. *Which of these are correct reasons for using insulated wire instead of bare wire?*
    - *a) Insulated wire lasts longer.*
    - *b) It is safer to handle than bare wire.*
    - *c) The covering keeps the wire cooler.*
    - *d) Insulated wire helps prevent short circuits.*
    - *e) The covering keeps the wire cleaner.*
    - *f) Current will not flow in an insulated wire.*



This experiment shows you how a fuse works.

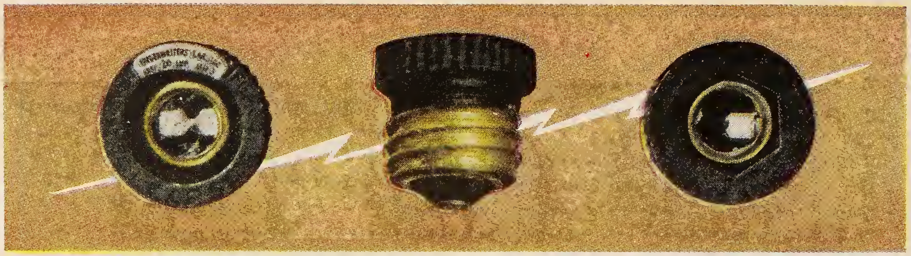
How do we protect our buildings from short circuits?

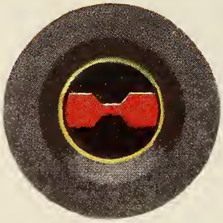
SOMETIMES A BUILDING catches fire because of a short circuit. But this is usually prevented. Scientists have worked out a way to protect our buildings from short circuits. In every building, there is a "policeman" on guard in the electric circuit. This "policeman" is called a *fuse*. All the current must flow through the fuse before it goes to the light bulbs, toasters, and other appliances.

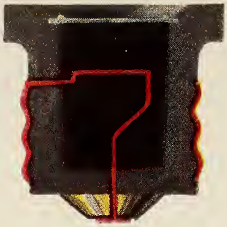
Have you ever seen what happens to a fuse when something goes wrong in an electric circuit? Perhaps your mother was using an electric iron when all at once something in the iron went s-s-s-s-t! In an instant, the current was off. Something in the iron or the cord had caused a short circuit. The current went off because the fuse was guarding your home against a short circuit. The fuse turned off the current.

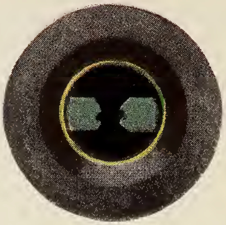
You can do an experiment to see how the current was turned off. First, get a new fuse and look through the cover. Inside, you can see a thin strip of metal. This strip of metal is the part that guards the circuit. Let us see how it does this.

Put a strip of tin foil on a block of wood. Connect two pieces of insulated copper wire to a dry cell. Hold the loose ends of the wires on the ends of the tin foil, as shown in the picture. The tin foil is a conductor of electric current. So the wires and the tin foil make a closed circuit. Watch the tin foil carefully. What happens to it?









When the tin foil melts, it breaks apart. Do you still have a closed circuit? What happens to the electric current? Will it still flow through the wires? What has broken the circuit?

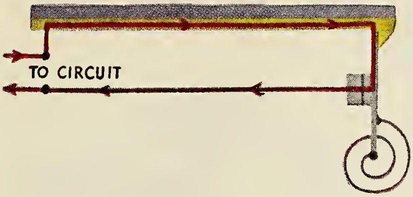
Why does the tin foil melt although the copper wires do not melt? You know that some metals melt easily while other metals need much heat to make them melt. The tin foil melts because only a little heat is needed to melt it. The copper wires do not get hot enough to melt.

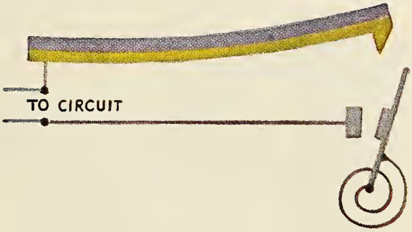
Now you can understand how a fuse turns off the current when there is a short circuit. A short circuit heats the wires. It also heats the strip of metal in the fuse. This metal needs only a little heat to make it melt. When the metal melts, it breaks the circuit. Then there is no longer a closed path through which current can flow. We usually say that the fuse has "burned out" or "blown out." Of course, the fuse did not really burn or burst. A strip of metal inside the fuse melted.

Look at the pictures on this page. They show a fuse and how the current goes through it. The fuse in the picture on the right is "burned out."

Before a new fuse is put in the circuit, we must get rid of the short circuit. Otherwise the new fuse will "burn out," too. The appliance or cord that caused the short circuit must be disconnected. It should not be used again until it has been repaired. Then when the new fuse is put in, the current can safely flow through its path of insulated wire.

Another kind of "policeman" is used to guard circuits. It is called a *circuit breaker,* and its name tells you what it does. Like a fuse, it breaks





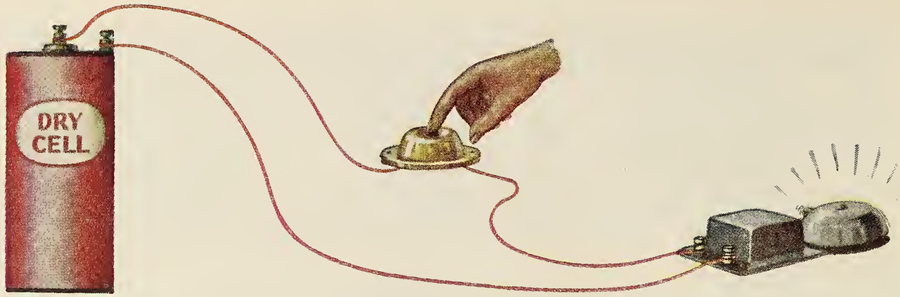
the path of the current whenever there is a short circuit. Heat bends a metal strip inside the circuit breaker until there is an open place in the circuit. You can reset the circuit breaker by pushing a lever. It does not have to be replaced as a fuse does. When the circuit breaker is reset, current flows through the circuit again. The picture on this page shows a circuit breaker. Follow the path of the current through the circuit breaker.

Safety rules for using fuses

1. Never try to repair a "burned-out" fuse. Use a new one.
2. When a fuse "burns out," always put in a new fuse that will carry the same current. If the old fuse is labeled 15A, the new fuse should be labeled 15A.
3. Never try to use a penny instead of a new fuse. The penny is made of copper. It will not melt until the copper wires do, too.
4. Always turn off the current when you put in a fuse. Otherwise you may get an electric shock.
5. Never stand on a damp floor in the basement when you put in a new fuse. Stand on a dry board.

---

1. *Why may a short circuit be dangerous?*
2. *Put these sentences in order so that they tell what happens when a fuse "burns out."*
   - *a) The metal strip in the fuse melts.*
   - *b) There is a short circuit.*
   - *c) The current stops flowing.*
   - *d) The metal strip in the fuse gets hot.*
   - *e) The circuit is broken.*
3. *Many homes and buildings now use circuit breakers instead of fuses. What do you think is a reason for this?*



How do we control electric current?

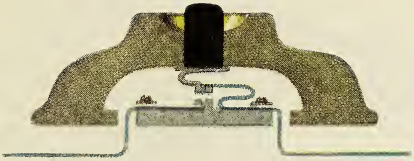
You come into a room and push a switch. The light goes on. You push the switch again, and the light goes out. In just about the same way, you turn a toaster, an iron, a radio, or any other electrical appliance on or off. The energy of electric current is certainly a handy form of energy to use, because it is so easy to turn on and off.

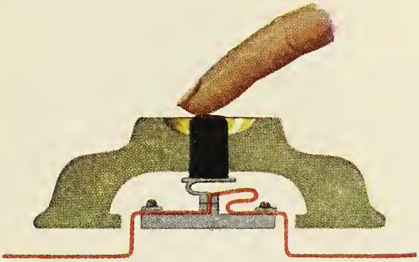
You have already learned enough about electric current to understand what happens when you turn the current on or off. To be sure that you can tell just what happens, try this experiment with a push button. Connect the push button and a bell to a dry cell, as shown in the picture. Does the bell ring as soon as all the wires are connected? Now press down on the button. What happens? Why?

If you take the push button apart, you can find out how it works. The picture shows the main parts of a push button. Do you see that the button pushes down on a small strip of brass? This strip of brass is a spring. One binding post of the push button is connected to this spring. When you press the button, you push the spring down on another piece of brass. This piece is connected to the other binding post of the push button. When the spring touches this piece of brass, the circuit is closed. Current flows through the circuit, and the bell rings.

When you take your finger off the button, the brass spring pushes up. This makes a break in the circuit. Current cannot flow through the open circuit. So the bell stops ringing. A push button is one kind of electric switch. As you know, switches are used to turn the current on and off. When you turn on the current, the switch closes the circuit. When you turn off the current, the switch opens the circuit. Switches help us control electric current by turning it on or off as we need it.

We can control the current in another way, too. We can make the current stronger or weaker. Scientists have discovered several ways to do





this. One way to make the current stronger is to connect several cells together. The storage battery in an automobile usually has three cells. They make a much stronger current than just one cell. Dry cells can also be connected together to make a stronger current, as you will see later in this unit.

Do you have an electric train? If you have one, you know that you cannot connect it directly to the current that comes into your home. You have to use a *transformer*. Without a transformer, the strong current would ruin the motor of your electric train. But the transformer controls this current so that just the right amount flows through the motor. A transformer like this is often used to ring doorbells, because they need only a small amount of current. Another kind of transformer is used to make an electric current stronger.

Safety rules for using switches

1. Have a switch repaired at once if you get a shock when you use it to turn current on or off.
2. Never touch a switch with wet hands. Also do not touch a switch when any part of your body is against a water pipe, a faucet, or radiator.

---

1. *Explain how a push button controls the electric current that rings a bell.*
2. *If you use dry cells in your experiments with electric current, what can you do to make the current stronger?*
3. *Suppose that we did not have switches. What would we have to do to turn the current on and off?*
4. *Why do we use a transformer to run toy electric trains and ring doorbells?*

How do we use electric current to make heat?

How many electric heating appliances can you find in your home? Your mother probably has an electric iron. At breakfast this morning, she may have used an electric toaster, an electric coffee pot, and even an electric egg cooker. Perhaps the stove in your kitchen uses electric current. On cold days, you may turn on an electric heater to warm the bathroom. When you are chilled, you may use an electric heating pad to warm yourself. There are even electric blankets!

All these heating appliances use electric current. But how do they change electric current to heat? In the experiment you did on page 131, you noticed that the wires became hot when a current flowed through them. And you know that an electric current can make the strip of metal in a fuse hot enough to melt it.

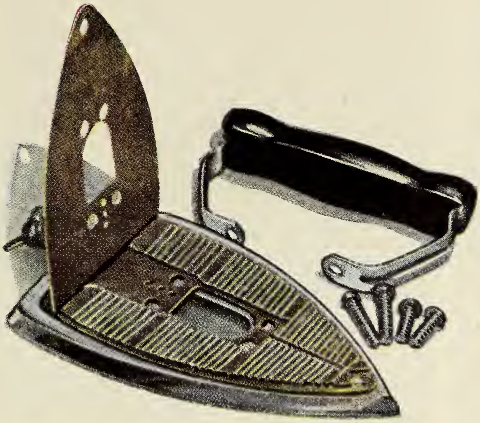
Now you can do an experiment to see how electric current is changed to heat. Connect a short, thin piece of iron wire between the binding posts of a dry cell. Watch the wire. Hold your finger near the wire from time to time but do not touch the wire. Does the wire get very hot?

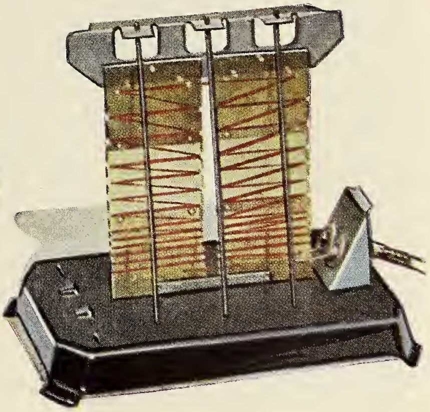
Iron wire is not such a good conductor of electric current as copper wire. It takes more energy to make a current flow through the iron wire. The energy used to make the current flow is changed into heat. Heat is a form of energy, as you know. The heat energy makes the iron wire hot.

Now you can understand how an electric toaster gets hot enough to toast bread or even burn it. Look at the inside of the toaster. You will see some wires, or you may see some thin, flat metal ribbons. Just by looking at them, you can probably tell that they are not made of copper. Connect the toaster to the electric current and watch the wires or ribbons get red-hot. These wires or ribbons make up the *heating element* of the electric toaster.

Every electric heating appliance has a heating element. The heating element changes the energy of electric current into heat energy. If you can get an old, worn-out electric iron, take it apart and see what made it get hot. Can you find the heating element? As electric current flowed through it, it became hot and heated the iron. The pictures on the next page show you the heating elements of an electric toaster and an electric iron.

Try to find the heating element in other electrical appliances. You will see that it is usually made of wire or flat metal ribbon. But if you look at an electric stove, you may find another kind of heating element. In many electric stoves, a metal rod is used instead of a wire, because it lasts much longer. But no matter what





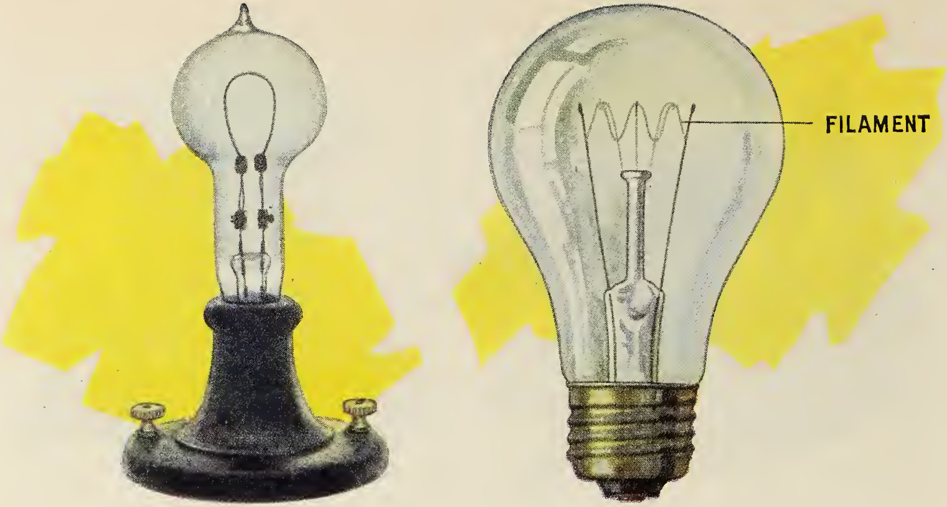
kind of heating element you find, you will know that it changes the energy of electric current into heat energy. We use this heat energy to cook our food, iron our clothes, and keep us warm.

Safety rules for using electric heaters

1. Never use a knife, fork, or spoon to get bread out of an electric toaster while it is turned on. You may get a shock or a burn. Or you may cause a short circuit.
2. Do not use a damp cloth to clean the outside of an electric heater while it is turned on. Disconnect the heater and wait until it cools.
3. Do not go away and leave an electric iron connected. It may set the ironing board on fire.
4. Do not hang wet clothes on an electric heater to dry. You may cause a short circuit or even a fire.
5. Never touch an electric heater while you are in a bathtub or when any part of your body is touching a water pipe, a faucet, or a radiator. Many people have been killed in this way.
6. If you use an electric heating pad, be sure that it has a waterproof cover. Otherwise you may get a shock if perspiration soaks into it.

---

1. *How does an electric current make some wires get hot?*
2. *In what way are all electric heating appliances alike?*
3. *The wires in our homes and other buildings do not get hot when current flows through them. Why?*



The picture on the left shows Edison's first electric-light bulb. On the right is the kind of bulb we use now. This large one has clear glass and you can see the parts.

How does electric current give us light?

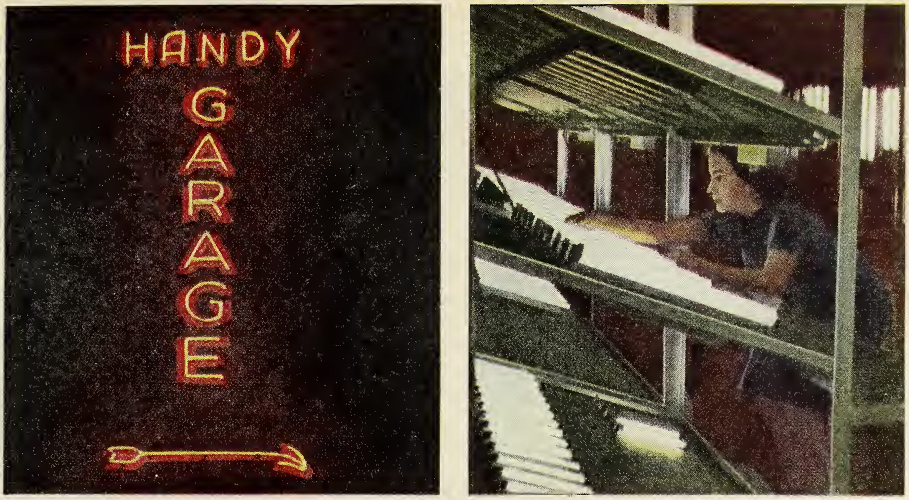
You already know some things that will help you understand how we get light from electric current. You have seen that a current can make wires hot. It can make them so hot that they glow. When anything glows, it gives light.

About seventy years ago, the famous American inventor, Thomas Edison, began to wonder whether there was not some way to make an electric lamp. The first thing that he had to find was a material that would give a bright light when it was heated. This material was very hard to find. It had to carry an electric current. And it had to get very, very hot without melting.

Edison tried hundreds of different materials, but none of them would do both of these things. At last, he made a thread of carbon that did what he wanted it to do. It carried an electric current, and it got very hot without melting. The first electric-light bulb had a carbon thread, or *filament*, in it.

But the carbon thread did not work very well. The hot carbon gave light, but the heat soon made the carbon fall to pieces. The first electric-light bulb lasted only about forty hours. So scientists went to work to find a better material. They wanted a material that would last longer and give more light.

To find out what material is used today, suppose that you get a worn-out electric-light bulb. Break it so that you can look at the inside. Wrap the bulb in cloth or paper when you



You probably have seen neon lights like this garage sign in your town. The girl in the other picture is inspecting fluorescent lamps in a factory where they are made.

break it to keep the glass from cutting you. Or hold the bulb under water. What do you find inside?

Inside the bulb, you see a fine, silver-colored wire. It is almost as thin as a hair on your head. This is the filament. Take hold of the filament and pull it out as far as you can. Do you see that it is a long wire that was coiled up into a small space? When a current flows through this wire, it heats the wire white-hot. Then the wire filament gives the light that we use.

The filament is made of a metal called tungsten. This metal lasts for hundreds of hours and gives a very bright light. It takes a great deal of energy to make an electric current flow through a tungsten wire. This energy is changed into a large amount of heat. The heat makes the wire white-hot, and the white-hot wire gives a very bright light.

Not many years ago, scientists discovered another way of using electric current to give light. They found that some gases will glow and give light when current flows through them. One of these gases is neon. The gas is sealed in a glass tube, and then a current is sent through it. Neon gas glows with an orange-red light. Other gases give light of different colors. Many advertising signs are made of glass tubes with these gases in them.

Of course, we do not use these glowing gases for lamps in our homes and buildings. But there is a new kind of lamp that we do use. You may have this kind in your home. It is called a *fluorescent* lamp. Fluorescent lamps use less current to give the same amount of light as ordinary bulbs do.

In junk yards, huge magnets are used to lift tons of iron and steel from the scrap piles. After you have read the next few pages, you will understand how these magnets work.

A fluorescent lamp has a glass tube shaped like a rod or a ring. Inside the tube is a small amount of the liquid metal called mercury. When a current flows through the tube, the mercury gets so hot that it changes to a gas. The gas gives off a certain kind of ray that we cannot see. The inside of the glass tube has a coating of special materials. The rays strike these materials in the glass tube and make them glow.

---

1. *Which is hotter, a red-hot wire or a white-hot wire?*
2. *What is a filament? How does it give light?*
3. *Why is copper wire not used in electric-light bulbs?*
4. *Explain why tungsten is a good material for filaments in light bulbs.*
5. *Why did scientists try to improve the first electric-light bulb?*
6. *How does a neon lamp give light?*
7. *What is a fluorescent lamp?*

How can we use electric current to make a magnet?

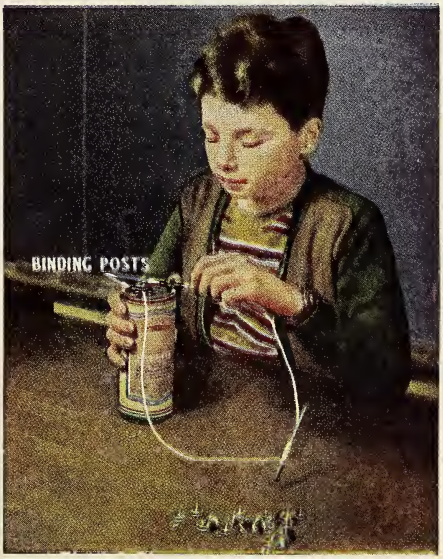
Did you ever see a machine like the one in the picture on page 142? It is called a crane, and it is used to pick up heavy loads. Some cranes use a hook to pick things up, but this crane uses a round, flat magnet. You can see cranes like this one in railroad yards, steel mills, junk yards, and other places where large amounts of iron and steel are loaded and unloaded.

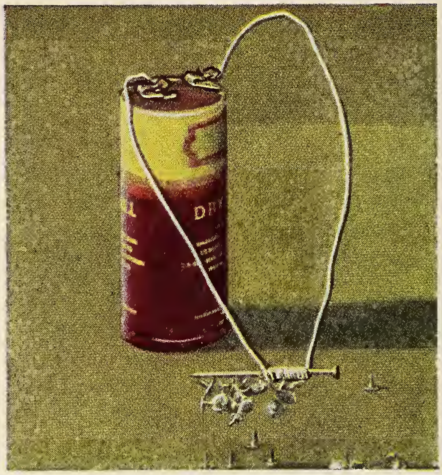
If you watch one of these cranes at work, you see it move out over a pile of iron or steel. The magnet is lowered until it touches the pile. When the magnet is lifted, tons of iron and steel may be clinging to it. You can see that the magnet must be very strong to lift this heavy weight. It is much stronger than any magnet you have used.

The crane moves along until the load of iron and steel is over a railroad car. Then all at once the metal drops into the car. Somehow the magnet has lost its force. Again and again, the crane moves from the pile of iron and steel to the railroad car and back again. Each time, it picks up a heavy load, carries it to the car, and then drops it.

Of course, you know that a man is making the crane work. He makes the crane move along to the place where he wants the magnet. But do you know why this magnet has so much force? And can you tell why the magnet suddenly loses its force? You can find the answers to these questions by doing some experiments. Follow the directions carefully.

Get a large nail or bolt. Dip it into some tacks made of iron or steel. Do any of the tacks stick to the nail or bolt? If no tacks stick, you know that the nail or bolt is not a magnet. Now get a piece of cotton-covered copper wire about two feet long. Scrape about an inch of the covering off each end of the wire. Then wind part of the wire tightly around the nail or bolt, as shown in the picture. Make about ten turns of the wire. Again dip the nail or bolt into the tacks. Is the nail or bolt a magnet? How do you know?





Now connect one end of the wire to one binding post of a dry cell. Connect the other end to the other binding post. Once more dip the nail or bolt into the tacks. What happens this time? Is the nail a magnet now? Disconnect one end of the wire from the dry cell. What happens? Why?

You have made an *electromagnet*. Electric current from the dry cell flowed through the wire wound around the nail or bolt. This made the nail or bolt into a magnet. Your electromagnet will attract things made of iron or steel. You know that iron and steel are called magnetic materials. But your electromagnet will not attract things made of nonmagnetic materials, such as glass, cloth, tin, lead, rubber, or wood. Try it and see.

The electromagnet is just like a bar magnet and a horseshoe magnet in one way. It attracts things made of iron and steel. But the electromagnet is different from these magnets in another way. Do you know what it is? The next experiment will help you find out.

First, pick up some tacks with a bar magnet or a horseshoe magnet. How can you get the tacks off the magnet? You have to pull them off. Now connect your electromagnet to the dry cell and pick up some tacks. How can you get the tacks off the electromagnet? Disconnect one end of the wire from the dry cell. What happens to the tacks? How is the electromagnet different from the bar magnet or the horseshoe magnet?

When you disconnect the wire, the tacks fall off. The nail or bolt is no longer a magnet. The circuit through the wire is broken, and current cannot flow through the wire. The electromagnet has no force to attract iron and steel unless current is flowing through the wire. As soon as the electric current is turned off, the electromagnet loses its force and drops its load of tacks.

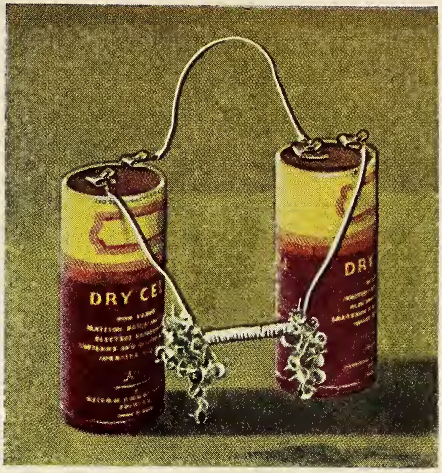
Now do you see one way that an electromagnet is different from other magnets? You cannot control the force of a bar magnet or a horseshoe magnet. But you can easily control the force of an electromagnet. All you have to do is turn the current on or off. An electromagnet is a magnet only when an electric current flows through the wire.

From what you have learned about electromagnets, you can explain how the crane picked up and dropped its loads of iron and steel. Of course, the magnet was an electromagnet. To pick up a load, the man turned on the current. The force of the electromagnet attracted the iron and steel. To drop the load, the man just turned off the current. At once, the electromagnet lost its force and the load of iron and steel fell.

Before you do any more experiments with electric current, you should learn something that will help keep the dry cells from wearing out too fast. When you are not using an electromagnet, always disconnect the wire from one binding post of the dry cell. Or you can put a switch in the circuit so that you can easily turn the current on or off.

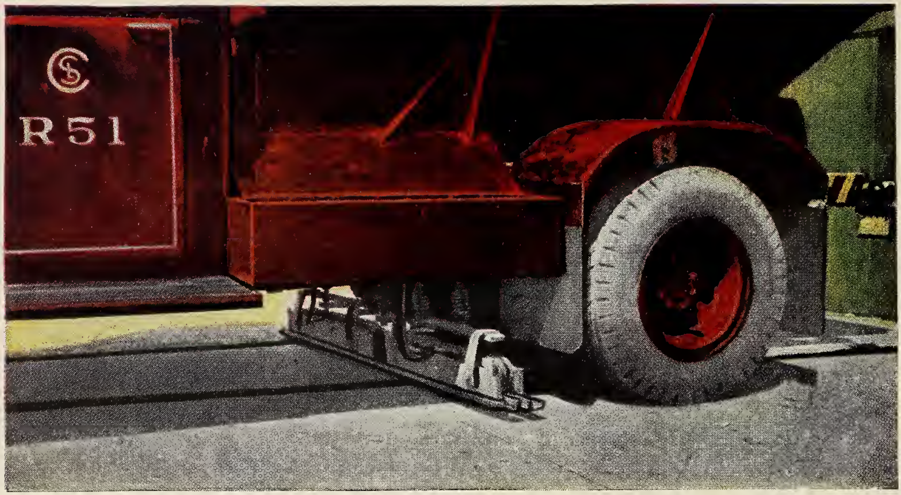
To pick up tons of iron and steel, an electromagnet must have a great deal of force. Scientists know how to make very strong electromagnets. These magnets have much more force than a bar magnet or a horseshoe magnet. Do you know how to make the force of an electromagnet stronger? Here is an experiment that will show you one way to do it.

Connect the electromagnet that you made to a dry cell. Count the number of tacks that it will pick up. Disconnect the wire from one binding post of the cell. Then wind more turns of wire around the nail or bolt. Connect the wire to the cell again. How many tacks will the electromagnet pick up this time? This experiment shows you that more turns of wire make an electromagnet stronger.



You can learn another way to make an electromagnet stronger by doing another experiment. Study the picture carefully to find out how to connect two dry cells to the electromagnet. Then connect the cells to the electromagnet. Count the number of tacks that it will pick up now. Did the electromagnet attract still more tacks? Two dry cells connected in this way make the current stronger than it is when only one dry cell is used. When a stronger current flows through the wire, the electromagnet has more force.

Electromagnets are useful because we can control their force and make them very strong. With an electromagnet, we can use an electric current



An electromagnet underneath this truck picks up nails and other pieces of metal from the road.

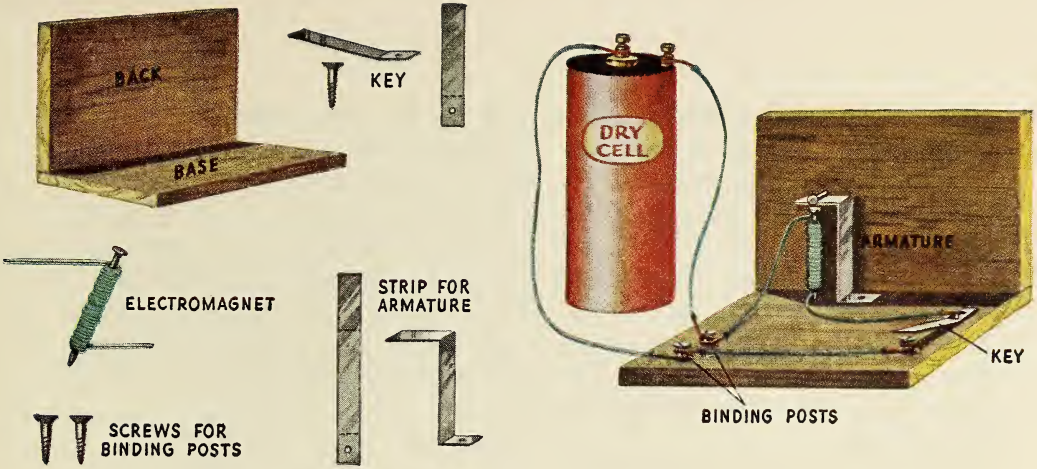
to move things. If you look around your home, you can probably find some electromagnets. Look for things that are moved by electric current. You will find that there is always an electromagnet in them.

---

1. *What things do you need to make an electromagnet?*
2. *How can you put these things together to make an electromagnet?*
3. *What are two ways to make an electromagnet stronger?*
4. *How is an electromagnet like a bar magnet or a horseshoe magnet? How is it different?*
5. *Why do you think electromagnets are useful?*

How does a telegraph work?

FOR A LONG TIME, people have wanted faster ways to send messages. But until the telegraph was invented about 100 years ago, there were no really fast ways to get news from one place to another place far away. You have probably read that an American inventor, Samuel F. B. Morse, made the first telegraph and sent the first message over wires. The telegraph was one of the first inventions to use an electromagnet.



This picture shows you the parts you need for making a telegraph set, and how to put the parts together.

You can easily learn how a telegraph works if you make a telegraph set like the one in the picture. First, make the *sounder*. This is the part that clicks when a telegraph is working. Get two pieces of soft wood. Use one piece for the base and the other for the back. Make the electromagnet by winding twenty-five or thirty turns of insulated copper wire around a large nail. Drive the nail part way into the base. It is a good idea to drill a small hole in the wood before you drive the nail. The hole will keep the nail from splitting the wood. Now nail the back to the base.

Next, cut a strip from a tin can. The strip should be about three quarters of an inch wide and four inches long. Of course, you know that the tin can is made of steel covered with a very thin layer of tin. Drill a little hole in one end of the strip. Then fasten it to the wood base with a screw. Bend the strip so that one end is about one eighth of an inch above the top of the nail. The strip will be the *armature*. It is the part that moves. Drive a small nail in the wood back just above the armature. To make binding posts for the wires, put two screws in the wood base. Connect the ends of the wire from the electromagnet to the binding posts.

Now make the *key*. Use a strip from a tin can. The strip should be the same size as the armature. Drill a small hole in one end of the strip. Fasten the strip to the wood with a screw, in the position shown in the picture. Bend the strip so that the other end is off the wood. Put another screw under this end of the strip. The strip should touch this screw when you push the end down. Connect the key and the sounder to a dry cell, as shown in the picture. Now you can find out how a telegraph works.

Push down on the key so that the strip touches the screw. Do you hear the sounder click? Can you tell why it clicks? The key is a kind of switch, or push button. When the key is pushed down, it closes the circuit. Current flows through the wire of the electromagnet. The magnet pulls down on the armature. When the armature hits the top of the nail, it makes a click.

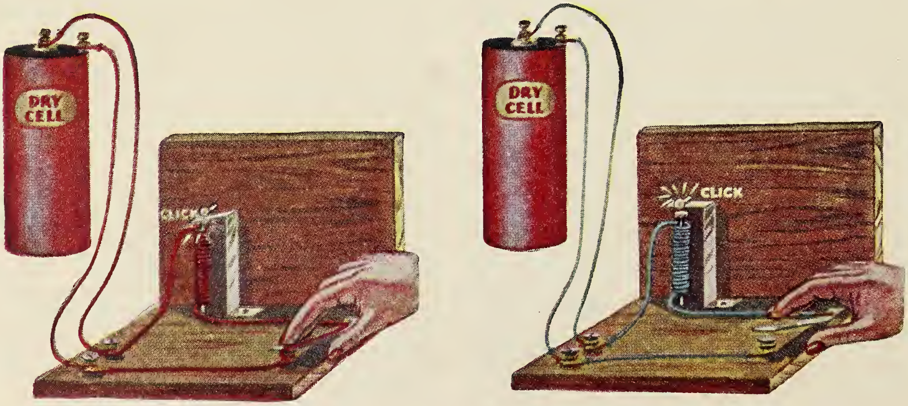
Now take your finger off the key. Do you hear the sounder click again? Can you tell why it clicks? When the key springs up, it breaks the circuit. Current no longer flows through the wire of the electromagnet. The magnet loses its force, and the armature springs away from the nail. When it hits the nail above, it makes another click.

To send messages with his telegraph, Morse worked out a *code* of dots and dashes for each letter of the alphabet. A dot is made by pushing the key down and letting it up quickly. This makes two clicks close together. A dash is made by holding the key down a little longer. This makes two clicks farther apart. Can you use the code on this page to send a message with your telegraph set?

A	· –	J	· – – –	R	· – – ·
B	– · · ·	K	– · –	S	· · ·
C	– · – ·	L	· – · ·	T	–
D	– · ·	M	– –	U	· · –
E	·	N	– ·	V	· · · –
F	· · – ·	O	– – –	W	· – –
G	– – ·	P	· – – ·	X	– · · –
H	· · · ·	Q	– – · –	Y	– · – –
I	· ·			Z	– – · ·

When you looked for electromagnets in your home, you looked for something that was moved by an electric current. The electromagnet in your telegraph sounder moved the

Look carefully at this picture to see how to use your telegraph set.



strip above it. This strip is the armature, as you know. The part that is moved by an electromagnet in any electrical device is also called the armature. You will see armatures in electric bells and motors.

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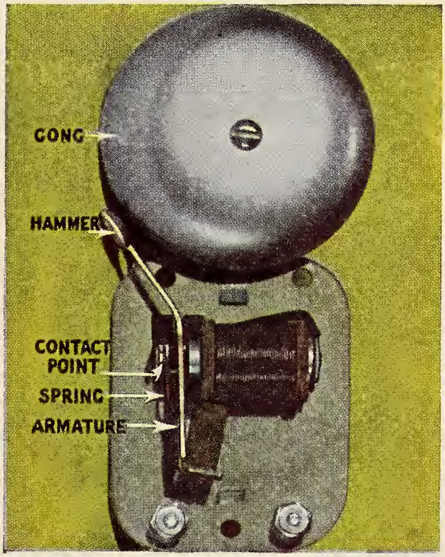
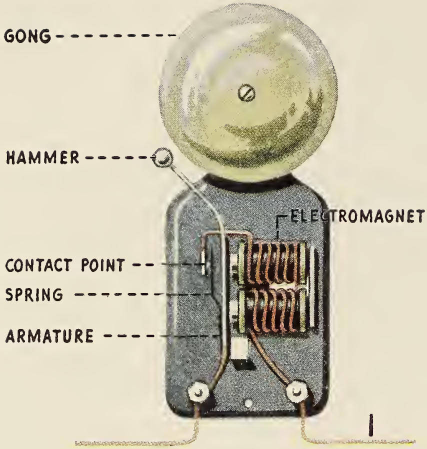
1. *When the key of a telegraph set is pushed down, what happens? Why?*
2. *What happens when the key is let up? Why?*
3. *How do telegraph operators make dots and dashes?*
4. *Could you use a bar magnet instead of an electromagnet in a telegraph sounder? Explain your answer.*
5. *Do you think you could find an armature in a toy electric train? Why?*

How does an electric bell ring?

PERHAPS YOU HEARD the doorbell ring while you were looking for electromagnets in your home. If you watched the bell, you saw the hammer move and hit the gong. Is there an electromagnet in the bell? The way to find out is to look inside. If you take off the boxlike metal cover, you can see one or two coils of wire wound around an iron rod. This is the electromagnet. Can you find the armature? It is the strip of iron near the electromagnet. The hammer that strikes the gong is fastened to the armature.

You know that an electric bell rings when you press down on a push button. The push button is a kind of switch. When you push it, it closes the circuit. Current flows through the wires, and the bell rings. It keeps on ringing as long as you hold the push button down. It does not stop until you take your finger off the button. Then the circuit is broken, and current no longer flows through the bell.





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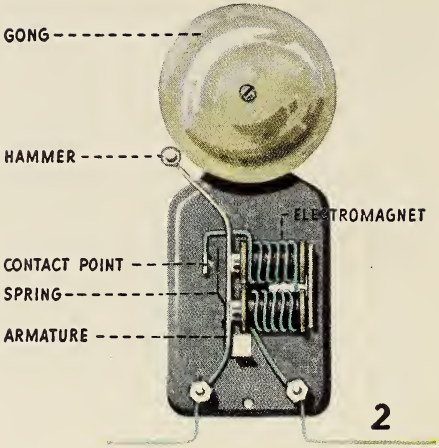


2

If you do this experiment, you can see what happens inside a bell when it rings. The cover should be off the bell. Connect the bell to a push button and a dry cell, as shown in the picture on page 136. Press the push button and watch the armature move quickly back and forth. Each time the armature moves toward the electromagnet, the hammer strikes the gong.

But why does the armature move back and forth? Take your finger off the push button and look at the bell when it is not ringing. Notice that a little metal spring is fastened to the armature. The tip of this spring touches the *contact point*. You can see the spring and the contact point in the picture.

The contact point and the spring work like a little switch inside the bell. When the spring touches the contact point, the switch is closed. If someone pushes the button now, current will flow through the electromagnet of the bell. Look at Picture 1. You see that the spring touches the contact point. When the current flows through the electromagnet, the armature is pulled toward the magnet and the hammer strikes the gong.

Push the armature against the electromagnet and hold it there. Is the spring now touching the contact point? You can see a little space between the spring and the contact point. This is a break in the circuit. So, of course, current cannot flow. Look at Picture 2. This shows how the circuit is broken when the spring is pulled away from the contact point.

When the circuit is broken, you know what will happen. No current flows. The electromagnet loses its force. It will no longer pull the armature to it. Now release the armature. You will see that it will move away from the electromagnet again. And the hammer moves away from the gong. Again, the spring touches the contact point as shown in Picture 1. Current flows through the electromagnet once more. The armature is pulled toward it and the hammer strikes the gong. All this happens over and over again many times a second. The bell keeps ringing as long as you hold the push button down.

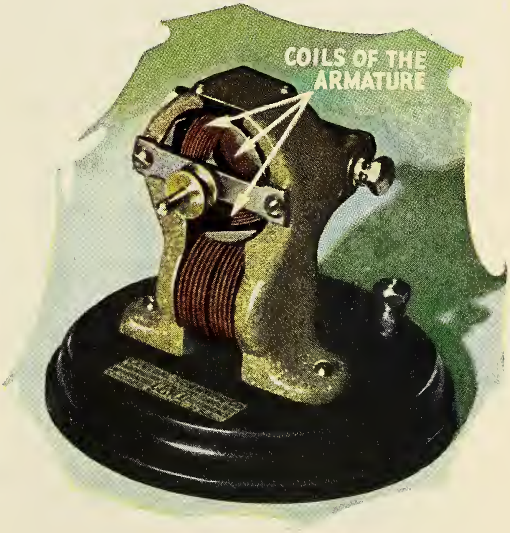
An electric buzzer works just like an electric bell. But a buzzer has no hammer and no gong. The buzzing sound is made by the armature as it moves quickly back and forth. If you can get a buzzer, take off the cover and find the different parts. Then connect the buzzer to a push button and a dry cell. Watch what happens when you press the push button down.

1. *What parts of an electric bell are the same as the parts of a telegraph sounder?*
2. *What part of a bell circuit is used like the key in a telegraph circuit?*
3. *Why is the armature of the bell pulled toward the electromagnet?*
4. *When the push button is held down, why does the hammer of a bell not stay against the gong?*

How does an electric motor run?

DID YOU SEE any electric motors while you were looking for electromagnets? Electric trains, fans, washing machines, and food mixers all have motors to make them go. There must be an electromagnet in an electric motor, because the motor has a part that moves. This part is called the armature, as you know.

The picture on this page shows a small toy motor. You can see three little electromagnets on the armature. There is a larger electromagnet fastened in the frame below. When the current is turned on, the three little electromagnets whirl around very fast.



Do you know why the electromagnets in the armature whirl around? Before you can find out, you will need to remember some things that you learned about magnets.

1. Every magnet has two poles. One is called the north pole, or N pole. The other is called the south pole, or S pole.

2. *Unlike* poles *attract* each other. An N pole and an S pole pull toward each other.

3. *Like* poles *repel* each other. An N pole pushes another N pole away. An S pole also pushes another S pole away.

Do you think that an electromagnet has an N pole and an S pole? To find out, do this experiment. Test an electromagnet with a bar magnet. Tie a string around the middle of the bar magnet. Fasten the string to a support so that the magnet can swing freely. Connect an electromagnet to a dry cell. Bring one end of the electromagnet near the N pole of the bar magnet. What happens?

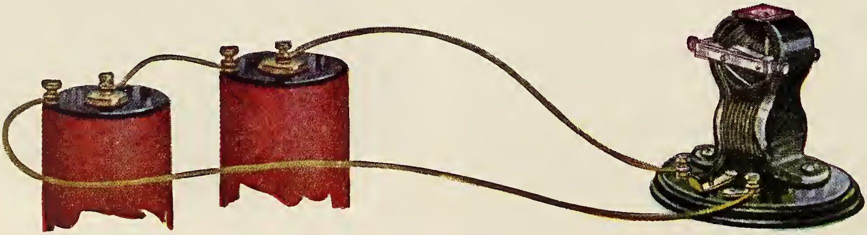
Now bring the same end of the electromagnet near the S pole of the bar magnet. What happens this time? Think of what you know about magnets. Does this experiment show that an electromagnet has an N pole and an S pole?

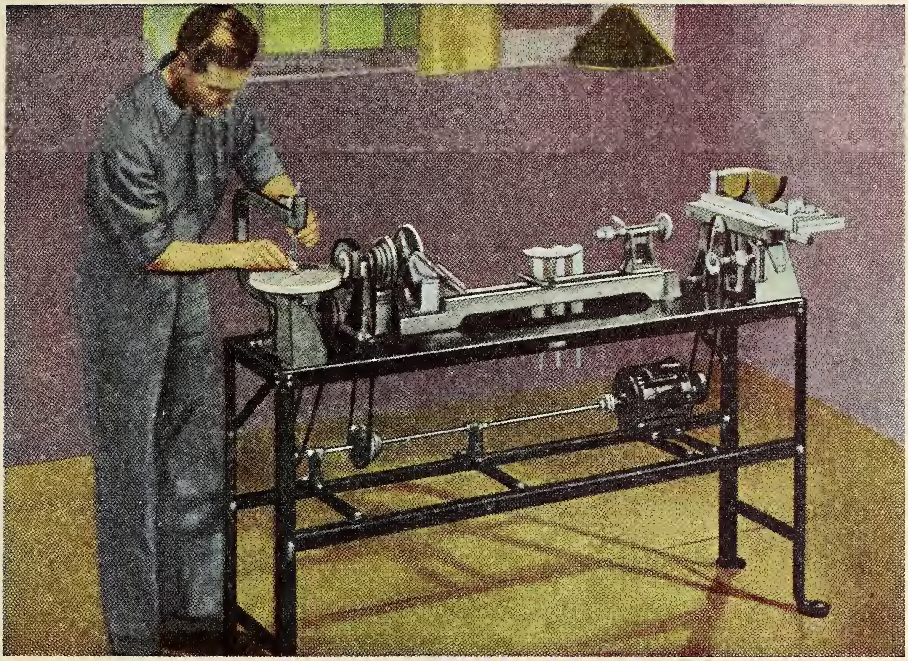
An electromagnet has an N pole and an S pole just like other magnets. If two electromagnets are brought near each other, they act just the way other magnets do. The unlike poles attract each other, and the like poles repel each other.

Now let us see how electromagnets can make a motor turn. An experiment will show you how magnets can pull and push each other. Tie a bar magnet to a support, just as you did before. Now hold the N pole of another bar magnet in front of the S pole of the hanging magnet. The hanging magnet will swing toward the magnet in your hand. Just before the magnets touch, take your magnet away.

Then hold the S pole of this magnet back of the S pole of the hanging magnet. The hanging magnet will swing away from the magnet in your hand. If you are careful, you can do this

The picture shows you how to connect a toy motor to two dry cells.



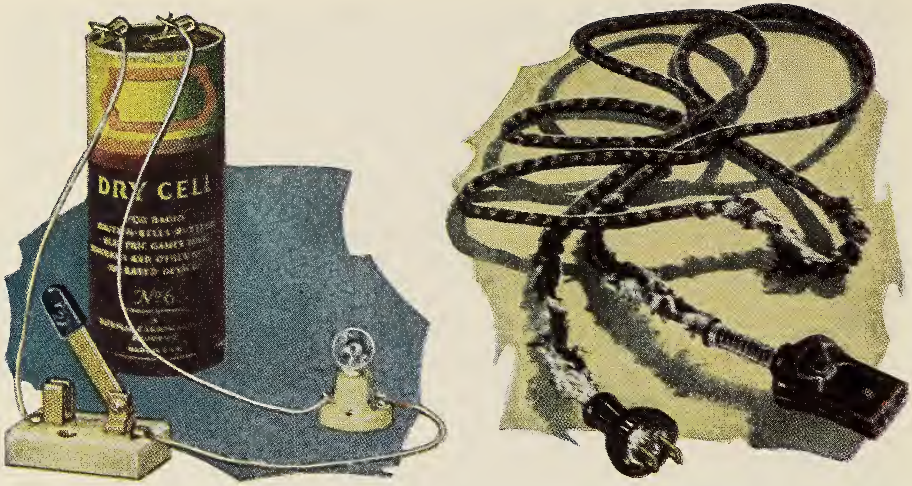


This man has a machine shop in his basement. He is going to use an electric motor to run his saw and other tools. By connecting the motor to the rod he can run several different tools with the same motor. Look at the picture to see how this is done.

over and over again. The hanging magnet will go around very fast. Try the experiment again. This time, use your electromagnet in place of the bar magnet that you held in your hand. Does the same thing happen this time?

In an electric motor, the electromagnets are arranged so that when the poles pull and push each other, the armature whirls around and around. Of course, the armature whirls only when the current is flowing through the electromagnets. When no current is flowing, the electromagnets have no force. Then the poles cannot pull or push each other and the armature does not move.

If you have a toy electric motor, connect it to some dry cells and make it run. The picture on page 152 shows you how to connect the cells to the motor. The motor will turn the wheels of toy machines. Of course, much bigger motors are used to drive the wheels of large machines. All over the world, electric motors are doing work by turning millions of wheels. Wher-



Will the current flow in the circuit pictured on the left? Why do you think so? Do you think it would be safe to use the cord shown in the other picture? Why?

ever wheels are turned by electric current, you can be sure that motors are making them go. And you know that electromagnets make the motors run.

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1. *What device can you always find in an electric motor?*
2. *Explain why a motor would not run if electromagnets did not have poles.*
3. *Why must the frame of a motor also be a magnet?*

QUESTIONS TO ANSWER

1. Why should you follow the safety rules when you use electric current?

2. Give three important ways in which we use electric current.

3. If the electric current goes off in your community, what things stop working? Make a list of these things.

4. What things might happen that would stop the electric current from flowing in your home?

5. How do we know that electric current has energy?

6. Suppose that you connected a toy motor and a switch to a dry cell, but the motor would not run. What things would you check to find out why the motor did not go?

7. How do you think motors are made strong enough to run big machines?

8. The sun and the force of gravity both help supply us with electric current. How do you think that they do this?

THINGS TO DO

1. Find out where your community gets its electric current. Visit the powerhouse if you can. What form of energy is used to run the generators?

2. Can you find a transformer on a pole near your home? Ask the electric company what this transformer does to the electric current.

3. Find out how storage batteries are charged.

4. If you have an electric stove, find out whether special wires are needed to carry the current. Are there special fuses for the stove? How are they different from the other fuses in your home?

5. Try to find fuses, switches, and other electrical devices in your school.

6. Visit a telegraph office and see how messages are sent.

7. Get an old electric heating pad and take it apart. Find out how it is insulated. What is the heating element made of?

8. Read about laying the first telegraph cable across the Atlantic Ocean.

9. Find out how much electric current costs in your community.

10. A *rheostat* is used to control electric current. Find out what rheostats are made of and how they work.

11. Read about Alexander Graham Bell and the invention of the telephone.

12. Watch for stories in the newspapers about accidents with electric current. Cut the stories out and make a Safety Scrapbook of these stories.

13. Find out whether there are electromagnets in a generator. Does a generator have an armature?

★ *In Unit Six You Will Learn* ★

★ *Where we get light* ★ *How light travels* ★ *When we can see things* ★
★ *Why you can see yourself in a mirror* ★ *What lenses do to light* ★
★ *How we can see things that are very small or far away* ★
★ *How we see things* ★ *Why things have different colors* ★

★ UNIT 6 ★

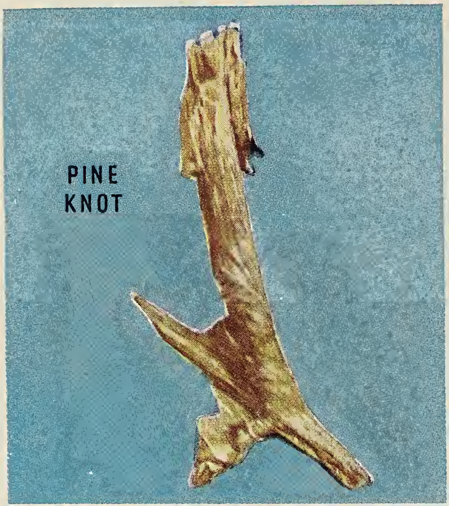
How Do We Use Light?

WHEN DO YOU use light? Perhaps you will answer, "I use light on dark days and at night." If you say that, you are only telling when you use *artificial* light. Artificial means made by some person or thing, or not natural. We get artificial light from electric-light bulbs, kerosene lamps, gas lamps, and candles. But you are using light every minute you are awake. Whenever you use your eyes, you are using light. If you do not believe this, shut yourself in a dark closet. Can you see anything without light?

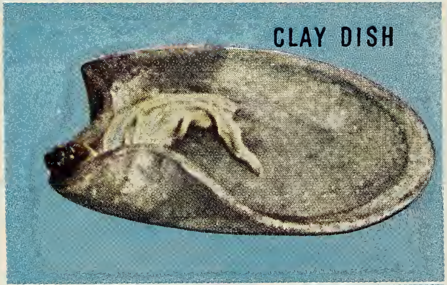
You can use light better if you understand some things about it. You can also explain many interesting things if you know how light acts. When the whistle on a steam engine blows at a distance from you, why do you see the "steam" before you hear the sound? Things appear to be much larger when you look at them through a microscope or a telescope than when you use just your naked eyes. Do you know why? You can see yourself in a mirror, but you cannot see yourself in a brick wall. After you have studied this unit, you will know how light acts. Then you should be able to explain how these and other interesting things happen. You will also know why you must take care of your eyes.

Where do we get light?

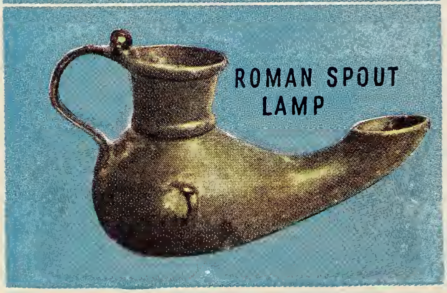
WE ARE SO USED to turning on electric lights that we just take artificial light for granted. But people lived on earth for a long time before they learned how to make any kind of light. The only light they had came from the sun. On dark days and at night, they lived in darkness. Some-



PINE KNOT



CLAY DISH



ROMAN SPOUT LAMP

times they saw red-hot lava pouring from volcanoes, or they saw light from trees that had caught fire when they were struck by lightning. At first, people were afraid of fire. They ran away from it. But after a while, people learned to use fire to get heat and light.

People found that they could pull a blazing stick from a fire and use it as a torch. They could carry this lighted torch with them. If they wanted to go to a stream or a lake for a drink at night, they could take the torch along. Or they could use it to light up a dark cave. They used several kinds of wood to make torches, but they found that pine knots made the brightest blaze. They also discovered that sticks smeared with grease would make a good light.

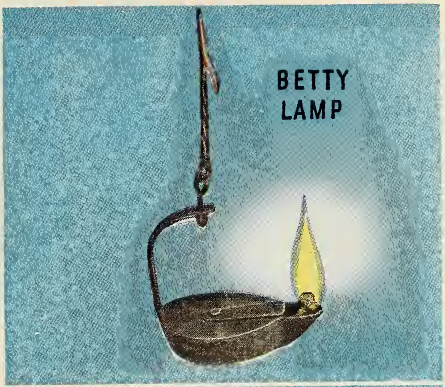
After many hundreds of years, people learned how to get oil from certain kinds of animals and plants. They put the oil in a hollow stone, a sea shell, an animal skull, or a little clay dish. When they set fire to the oil, it gave light. After a time, someone thought of a better way to make light. Fibers from plants were woven into a strip to make a wick. One end of the wick was set in a bowl of oil. When the wick had soaked up some of the oil, the other end was lighted. This lamp gave a better light, and it burned longer. The light could be controlled by using a big wick or a little one.

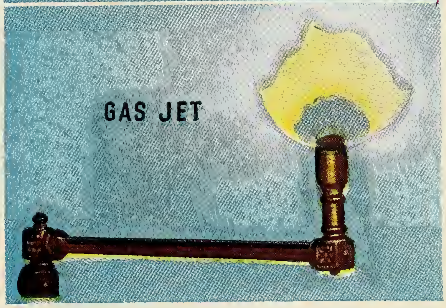
The Roman spout lamp and the Betty lamp were oil lamps. They had simple wicks that hung out of the spouts. The early settlers in New England used Betty lamps. They could stick the sharp pointed hook in between the stones of the fireplace.

Long after people first used oil, they learned how to make candles. They poured hot, liquid wax around a wick. When the wax cooled, it hardened. This made a candle. Candles were much better than bowls of oil, because they could be carried around.

Then about 100 years ago, an exciting discovery was made in Pennsylvania. A huge supply of thick, black oil was found in the earth. From this oil, kerosene was made. Kerosene was burned in lamps with wicks and glass chimneys. It gave a much better light than candles. In homes that do not have electric current, kerosene lamps are still used. But the light from a kerosene lamp is not very bright, and it is a nuisance to take care of the lamp. It has to be filled with kerosene. The wick must be trimmed so that it will burn evenly, and the chimney must be washed almost every day.

The search for an even better light went on. Scientists had been experimenting with a gas that comes from coal when coal is heated. This gas burns easily. Special lamps were invented to use the burning gas for light. Then large amounts of another gas were found in the earth when men drilled for oil. This *natural gas* was piped to cities to supply a cheaper and better light than people had ever used before. We still use much natural gas and coal gas for cooking.





All this time, people had been burning something to get light. Wood, oil, wax, kerosene, and gas were the materials that they burned. But you know that a material is soon used up when you burn it. Then you must get more material before you can have light again. Scientists kept trying to find some way of getting light without burning a material.

Then about seventy years ago, Thomas Edison found a way to use electric current to get light. In his first electric-light bulb, he put a filament of carbon. It glowed brightly when a current flowed through it. Edison found that the carbon filament would burn up quickly if there was air around it. He wanted to get light without having a material burn. So he put the filament inside a glass bulb. Then he pumped almost all the air out of the bulb. His first electric lamp would give light for about forty hours before the filament was used up.

Today we have much better electric lights, as you know. The filament in an electric lamp is now made of tungsten. This metal gives a much brighter light than carbon, and it lasts much longer. A lamp with a tungsten filament can be turned on and off many times before it wears out. Fluorescent lamps use mercury vapor to give light. They have no filaments, and they last a long time.

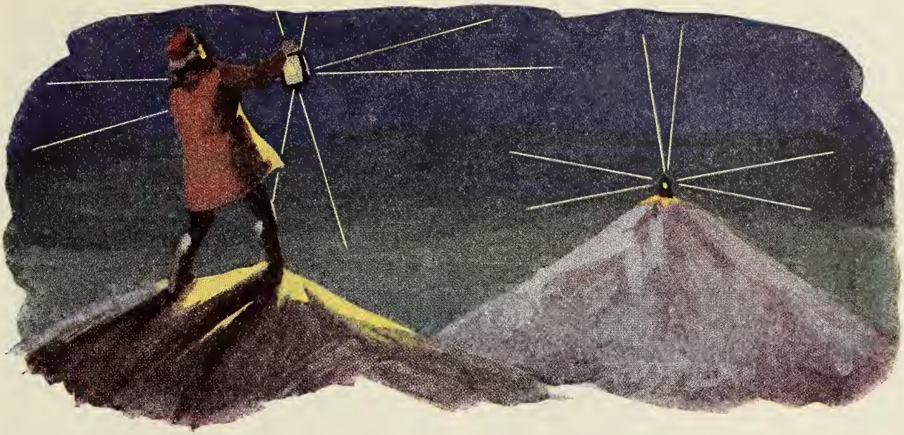
1. *What different ways have people used to light their homes?*
2. *Name some discoveries that helped people to get a better light.*
3. *How is an electric lamp different from a kerosene lamp or a candle?*
4. *Why would you rather have your home lighted by electric current than by kerosene?*

How does light travel?

ABOUT THE TIME that the first settlers were coming from Europe to America, there lived in Italy one of the most famous scientists the world has ever known. His name was Galileo. One day, he was thinking about what light does. He began to wonder whether light took time to reach his eyes. He asked himself this question, "If someone lights a lamp far away from me, do I see the light at once? Or does it take time for the light to reach me?"

Galileo was a great scientist. He experimented to see whether he could find out what is true. He did not just guess. Before he tried to find out why things happened, he did some experiments. To answer his question about light, Galileo worked out an experiment. He sent some men up on a high hill with a lantern. The lantern had shutters that could be opened and closed very quickly.

Before the men left, Galileo said to them, "I will stand on top of another high hill several miles away with a lantern like yours. As soon as you see



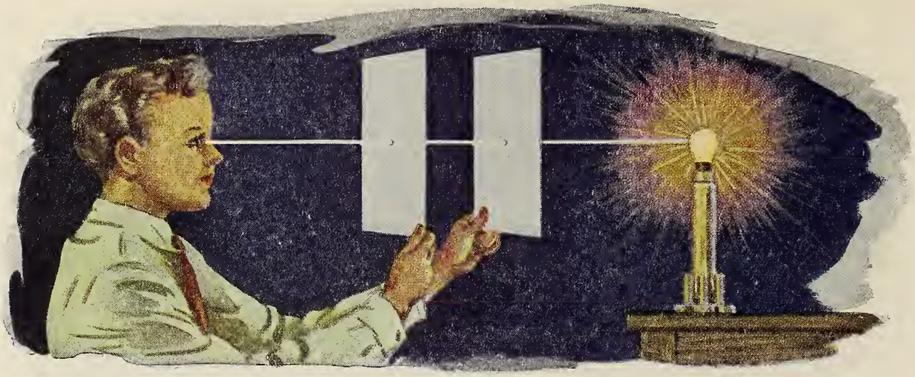
me flash my light, flash yours. Maybe I can find out how long it takes for you to see my light and for me to see yours."

The experiment was tried one night, but it failed. Galileo never found the answer to his question. Scientists know now that this simple experiment could not tell Galileo what he wanted to find out because it took the men a second or two to open the shutters of their lantern. But Galileo was on the right track when he thought that light moves and that it takes time to move.

Not long after Galileo's experiment, a Danish scientist figured out how fast light travels. It travels at the very high speed of about 186,000 miles a second! At that time, few people believed that anything could travel so fast. But just a few years ago, other scientists did an experiment that was much like the one that Galileo tried. This time, they had a special way of flashing the light and finding how long it took light to travel to a far-off mountain and back. The experiment showed that light travels at the speed of 186,284 miles a second. This is faster than any other speed you have heard of.

You remember that sound travels about 1100 feet a second through air. Light travels nearly a million times as fast as sound. Now do you understand why you see the "steam" from a distant whistle before you hear the sound? Light from the steam travels much faster than the sound from the whistle.

You can also explain why you hear thunder after you see lightning. The lightning and the thunder happen at the same time, but the light from the flash travels much faster than the sound. Whether it comes from the sun, the lightning, an electric lamp, or a candle, all light travels at this same high speed.



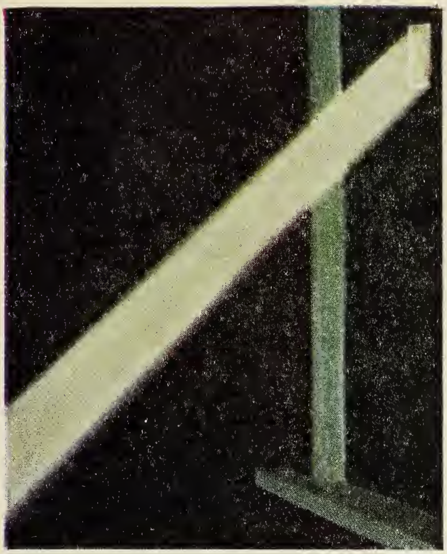
Now suppose you do an experiment to find out more about how light travels. Get two pieces of cardboard. Punch a small hole in the center of each piece. Take one piece in each hand. Close one eye. Hold the pieces between your other eye and a lighted electric lamp so that you can see light through both holes. Now move one piece of cardboard a little to one side. Can you see the light now?

You find that you cannot see the light unless the two holes are in a straight line with the light. This is shown in the picture on this page. The two holes have to be in line with the lamp because light travels in straight lines from the lamp.

Now try another experiment to see whether this is true. Get a piece of brown wrapping paper big enough to cover a window through which the sun is shining. Cut a square hole in the paper and pin the paper over the window. Darken the room as much as you can. Then look at the light coming through the hole. If you cannot see the light very plainly, put some chalk dust from erasers in the path of the light. The picture at the left on the next page shows what the path of the sunlight looks like. Is the light traveling in a straight line? How do you know? What would the path of the light look like if light did not travel in straight lines?

Hold a book so that the sunlight falls directly on it. Why does the book make a shadow? The light cannot go through the book and it cannot go around it. If the light could go around the book, there would be no shadow. What does this experiment show you about the way light travels?

You can see how light travels by doing still another experiment. Darken the room as you did before. Shine a flashlight on a ball or globe as the boy in the right-hand picture on the next page is doing. If light curves, the whole ball or globe will be lighted.



Here is another interesting thing about how light travels. If you walk around a lighted lamp or candle, you can see it from all sides. You can also see it if you look down at it or up at it. This shows that light travels outward in all directions from anything that glows. It travels up, down, and out from all sides. That is why one lamp placed in the center of a room can light the floor, the ceiling, and the walls.

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1. *Give a reason why Galileo's experiment failed to show him how fast light travels.*
2. *Which of these sentences are true? Explain your answer.*
   - *a) Sunlight moves faster than candlelight.*
   - *b) Sound travels almost a million times as fast as light.*
   - *c) Light travels in a straight path.*
   - *d) Light travels in only one direction from a glowing material.*
3. *The moon is about 240,000 miles from the earth. About how long does it take for light to travel from the moon to the earth?*
4. *Tell three important things that you have learned about how light travels.*
5. *Why do things make shadows when a bright light shines on them?*

When can we see things?

You may think that you already know the answer to the question, "When can we see things?" The answer seems to be "We can see things when we look at them." This answer is correct as far as it goes. But it is also true that we cannot always see things even when we do look at them.

Suppose that you go into a pitch-dark room at night. You cannot see a thing. There are chairs, tables, pictures, and other things in the room. They are right in front of your eyes, but still you cannot see them. Now suppose that you turn on an electric lamp. You can see the lamp because it gives light. Light travels from the lamp to your eyes. That is why you can see it. Lighted kerosene lamps, matches, and candles give light, too. So you can also see them. The sun gives so much light that it is dangerous for us to look straight at it. We can see anything that glows, because it produces light that travels to our eyes.

These white stripes marking the runway at an airport are made with a paint that glows.

But what about things that do not glow? Why can we see them? Get a mirror and watch what happens when light strikes it. Hold the mirror so that light from the sun shines directly on it. Now move the mirror around until it makes a spot of light on the wall or ceiling. You can see that this spot of light comes from the mirror, because the spot moves as you move the mirror. The mirror is like a ball player. The mirror "catches" the light and "throws" it on the wall.

When scientists talk about light, they do not say that a mirror "throws" light. They say that the mirror reflects light. As you know, reflect means throw back. A mirror will reflect almost all the light that strikes it. So the spot of light on the wall or ceiling will be very bright.

Now put a pan of water in the sunlight. Look for a spot of light on the wall or ceiling. You see that the smooth surface of the water will reflect light, too. Any very smooth material will reflect light. Mirrors are sometimes made by polishing a piece of metal until it is very smooth.

How is this reflection different from the one in the picture on page 156?

Look again at the pan of water that is reflecting the light. Notice how smooth the surface of the water is. Now stir up the water so that its surface is rough. What happens to the spot of light? The spot looks wavy. It is not so bright as it was, either.

When the surface of the water was smooth, it reflected the light all in one direction. This made a bright spot. But when the surface was rough, the light was reflected in different directions. This scattered the light. So the spot looked wavy and not so bright. Smooth surfaces reflect more light than rough surfaces.

Now let us see if other materials reflect light. Get a piece of brown wrapping paper big enough to cover a window through which the sun is shining. Cut a hole about an inch square in the paper and pin the paper over the window. Darken the room as much as you can. Then hold a piece of glossy, white cardboard in the path of the sunlight that shines through the hole. Does the cardboard reflect light? How do you know? Try blotting paper, white cloth, and other materials. Use some dark-colored materials, too. Which materials reflect the most light? Which reflect the least?

The experiments show that many materials reflect light. Some materials reflect more light than others. You can see a thing when it reflects light to your eyes. The more light that is reflected, the brighter the thing looks. In a very dark room, you can often see the faces of people. But you cannot see the rest of them if they are wearing dark clothes. The same amount of light falls on both the faces and the dark clothes. But the dark clothes reflect only part of the light. The faces reflect more of it.

The dark clothes keep part of the light. We say that they *absorb* part of the light. Absorb means take in, or soak up. Light-colored materials reflect most of the light that strikes them. Dark-colored materials absorb much of the light and reflect only a little.

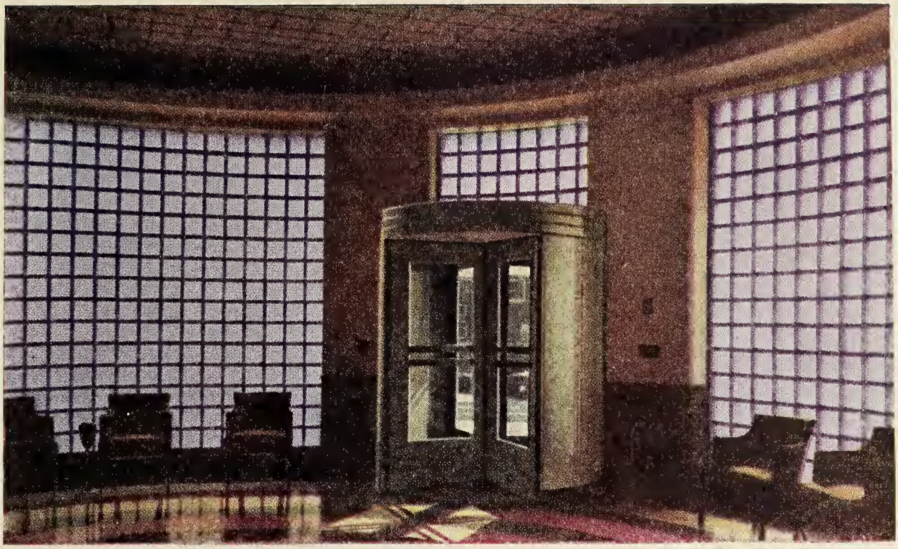
Did you ever make shadow pictures on a wall? To do this, you must be between the light and the wall. Then you will throw a shadow on the wall. The shadow shows as a black spot because light cannot travel through your body. Your body stops it. So part of the wall behind you is not lighted.

A material through which light cannot travel is called an *opaque* material. If there is an opaque material between you and an object, you cannot see the object. Light travels in straight lines. The opaque material cuts off the light that is reflected from the object toward you. So you cannot see the object.

Not all materials are opaque. Light can travel through some materials. You cannot make a dark shadow with a piece of window glass, because light goes through the clear glass. When so much light goes through a material that you can see things on the other side of it, we say that the material is *transparent.* Air is transparent. So is clear water.

You have probably seen glass through which light can come although you can not see through it. Electric-light bulbs, lamp shades, doors, and windows are often made of this glass. Any material that lets light through although you cannot see through it, is called *translucent.* Thin paper and cloth are translucent.

Now you have learned several important things about light. You know that you can see some things because they glow and send light to your eyes. You can see other things because they reflect light to your eyes. Of course, the light that is reflected comes from something else that glows. It comes from the sun, an electric lamp, a candle, or some other thing that gives light.



Look at this picture and tell which parts of the room are opaque, which parts are translucent, and which part is transparent.

When a thing reflects some light to your eyes, you can see it. If all of the light is absorbed, you cannot see the thing at all. You cannot see around the corner of a building, because the building is opaque and light travels in straight lines. Light cannot go through the building, and it cannot curve around the corner. You can see through air and clear glass. They are transparent. Light can go through translucent materials. But you cannot see through translucent materials even though light goes through them.

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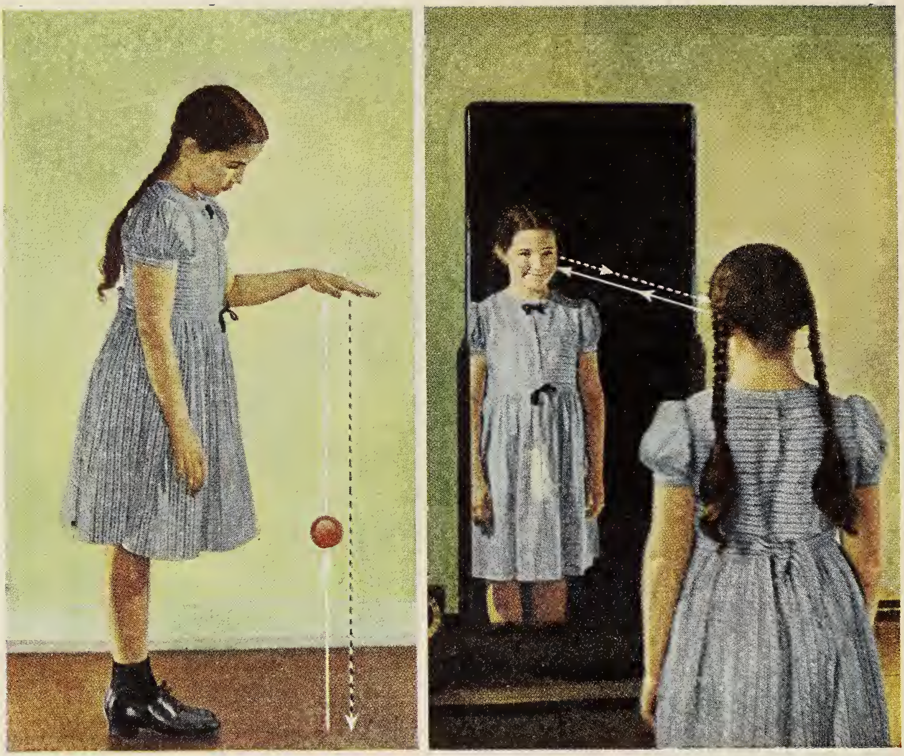
1. *Why can you see the sun or a lighted lamp?*
2. *Explain why you can see this book.*
3. *Why does a mirror reflect more light than white cardboard?*
4. *Why is a wet street shinier than a dry street?*
5. *You cannot see anything unless there is some light. Explain why this is true.*
6. *How is an opaque material different from a transparent material? How is a translucent material different from a transparent material? Give an example of each kind of material.*
7. *Why does a dirty mirror reflect less light than a clean mirror?*



Why can you see yourself in a mirror?

Have you ever watched a dog looking at itself in a mirror? Perhaps you heard it growl at itself. Even young children are puzzled when they first see themselves in a mirror. When some savages see mirrors for the first time, they do not realize they are looking at themselves. And, of course, they do not have the slightest idea why they can see themselves in a piece of glass.

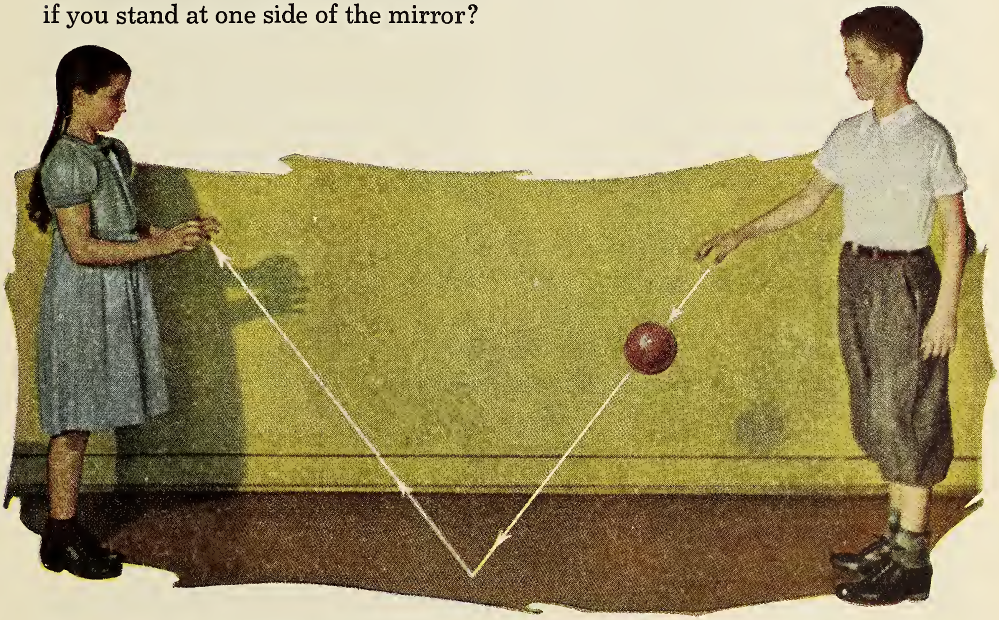
Do you know why you can see yourself in a mirror? You probably know that the back of the glass is covered with a silvery material. Is it the glass that makes you see yourself? Or is it the silvery material on the back of the glass? If you remember what you have learned about light, you should be able to answer these questions. You should also be able to explain why you cannot see yourself when you stand at one side of a mirror. You can see the mirror, but you cannot see yourself.

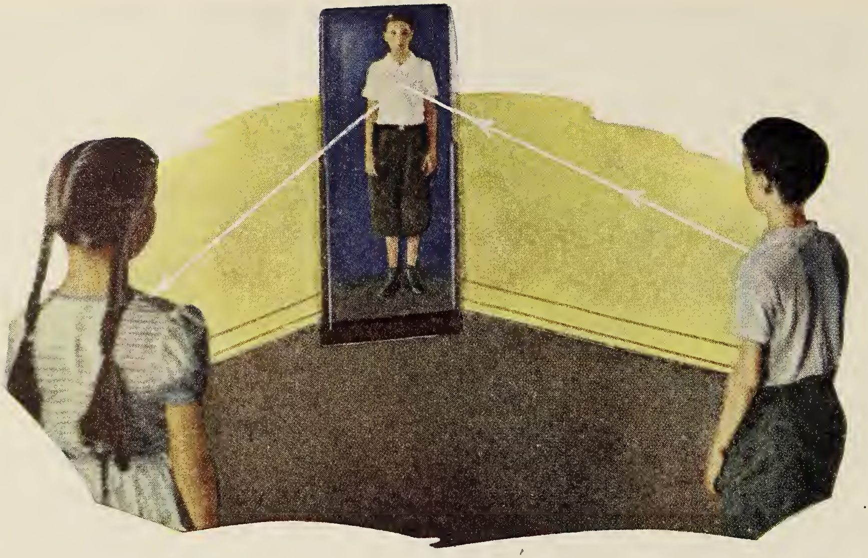
When you look at your shoes or your clothes in a mirror, you are not really looking at the shoes or the clothes. The light is not traveling directly from them to your eyes. It is traveling from the shoes or the clothes to the glass of the mirror. It goes through the glass and strikes the silvery material on the back of the glass. This material is opaque. It reflects the light to your eyes. So you really see the reflection of your shoes or your clothes in the mirror.

What happens is very much like this. If you bounce a ball on the floor, the ball bounces straight back up against your hand. You can catch the ball. When you stand directly in front of a mirror, the light from you is reflected straight into the mirror. Then it is reflected straight back to your eyes. They can "catch" the light.

Now why can you not see yourself if you stand at one side of the mirror? Think of a bouncing ball again. If you throw the ball down to the floor at a slant, the ball bounces away from you. Have a boy and a girl in your class bounce a ball from one to the other. The boy should throw the ball down at a slant toward the girl. As it bounces toward her, she can catch it. Watch the ball very carefully as it bounces from one to the other. It goes down toward the floor at a slant. Does it bounce up at a slant toward the other child? Is the slant about the same both times?

Now let us find out whether light travels to the mirror in the same way that the ball bounces. If you stand at one side of the mirror, light from you will slant toward the mirror and then





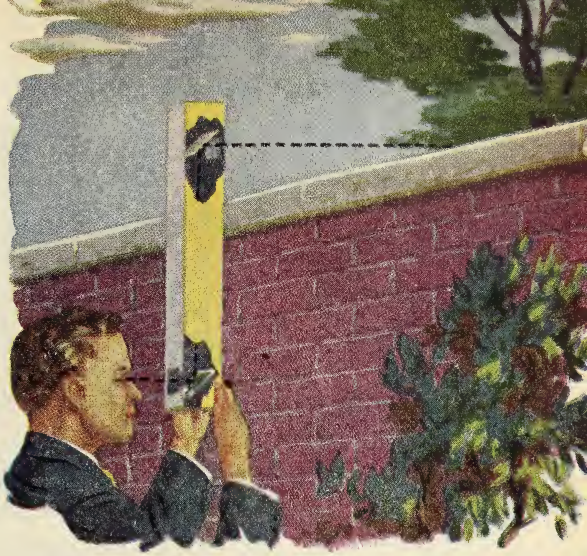
be reflected. But where will the light go? If it acts like the ball, it will travel away from the mirror at a slant. And the slant will be away from you.

Where would you have a child stand to see this reflected light? Have him stand at the other side of the mirror. He should be at the same distance from the side of the mirror as you are. Then he can see you, and you can see him. Now have him move three feet farther to the side. Can you see him now when you look in the mirror? What must you do to see him again? Try this to see if it will work. When light strikes a mirror at a slant, it is reflected from the mirror at the same slant. But the slant is in the opposite direction.

People in a submarine can see above water when the submarine is under the surface. To do this, they use mirrors. A long tube called a *periscope* can be raised or lowered from the submarine. There is a mirror at the top of the tube and another at the bottom. The top mirror is slanted so that light is reflected down the tube. The bottom mirror is also slanted so that light is reflected through an opening in the side. These mirrors make it possible to see what is happening above water. Scientists know just how to place these mirrors. They know that light is reflected from a mirror at the same slant that it strikes the mirror. But the light is reflected in the opposite direction.

You can easily make a periscope. Then you can use it to see over walls and around corners. Get a cardboard tube or a narrow wooden box. You also need two mirrors. Study the picture to find out how to make the periscope. Be sure to place the two mirrors at just the right slant.

In the picture, the light from the sun strikes a tree. Then the tree reflects light to the top mirror. This mirror reflects this light at the same slant in the opposite direction. Then the light strikes the bottom mirror. Again it is reflected at the same slant in the opposite direction. This time, it strikes a person's eye. Then he sees the tree.



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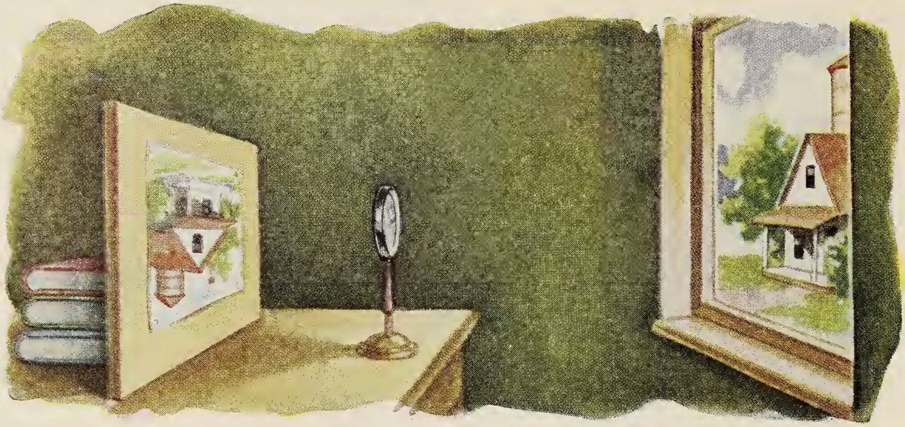
1. *Where should you stand if you want to see yourself in a mirror? Why?*
2. *How can you see the reflection of a tree in a still pond?*
3. *If the wind is blowing on a pond, how will the reflection of a tree be different from the reflection when the water is still?*
4. *How could you use a mirror to light up the dark corner of a room?*
5. *Why can you not see yourself in a mirror if you stand at one side of the mirror?*

What do lenses do to light?

YOU ALREADY KNOW what a lens is. It is a curved piece of glass. Now you can do some experiments to find out what a lens does to light. First, hold a piece of white paper in front of an open window. You can see that light falls on the paper, and the paper looks a little brighter. Now shut the window. The light that falls on the paper must go through the transparent glass. Look at the paper again. If the window is clean, the paper will look just as bright as it did before. The flat glass does not do anything to the light.

Now see what happens when light goes through a reading glass. A reading glass is a lens. Hold the paper about four feet from the window. Move the lens back and forth between the window and the paper until you see a picture on the paper. Make this picture as clear as you can on the paper. What is it a picture of? Look



If you have a reading glass, do an experiment like this one.

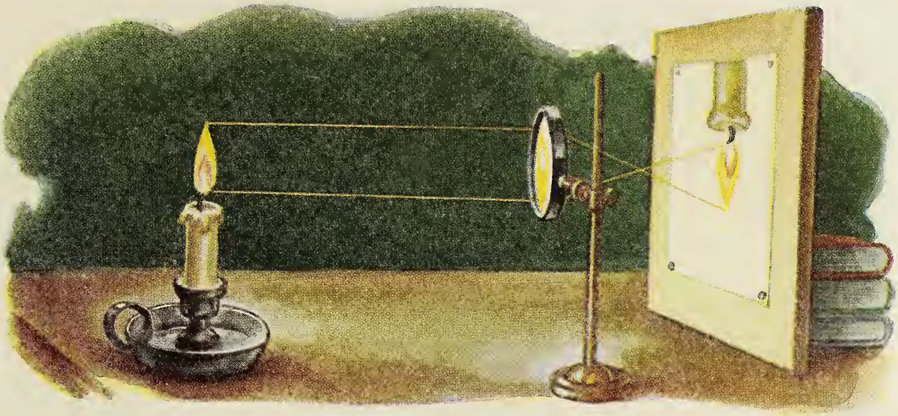
out of the window and then look at the picture on the paper. You see that it is a picture of what you can see outdoors. But there is a big difference. The picture on the paper shows everything upside down!

You can find out what happens if you do another experiment. Light a candle and set it on a table. Then darken the room as much as you can. Hold the reading glass about a foot from the candle. Then hold a piece of white paper back of the reading glass. Move the paper backward or forward until there is a clear picture of the candle on the paper. When the picture is clear, we say that the lens is *focused.* You can see that the picture of the candle is upside down, just as the other picture was.

Now let us find out why the picture is upside down. First, look at the lens. You know that it is made of glass. But the lens is not flat like a piece of window glass. It is curved. You can see that it is thicker in the middle than it is at the edge. You know that light travels in a straight line through a transparent material. What happens when light strikes the curved glass of the lens?

Light from the top of the candle flame goes straight to the top of the lens. When it goes into the glass, it is bent. The picture of the candle flame is upside down. So the light that goes into the top of the lens must be bent downward by the curved glass. The light from the bottom of the candle flame goes straight to the bottom of the lens. So it must be bent upward by the lens. That is exactly what happens. The lens bends the light so that you see the candle upside down.

Another experiment will show you how the lens in a moving-picture machine makes a large picture on a screen. First, focus the lens of the



This picture will help you see why the image that is made by a lens is upside down.

reading glass and get a clear picture of a candle flame on a piece of paper. Is the picture larger or smaller than the candle flame? Now move the candle closer to the lens. The picture is no longer clear. We say that it is now *out of focus.* Move the paper away from the lens until the picture is once more *in focus.* Is the picture larger or smaller? Move the candle still closer to the lens and focus it again. What happens? Do you find that as you move the candle closer to the lens, you have to move the paper farther away from the lens?

There is a lens in a machine used to show slides. Look at this lens. Does it have the same shape as the one in the reading glass? Then how do you suppose the slides appear right side up on the screen? Study the picture on the next page. You will see that the slide is put into the machine upside down. So it appears right side up on the screen. The lens bends light in the same way that the lens in a reading glass bends light.

A camera has a lens, too. Light from the thing that is photographed goes through the lens. The lens bends the light until it comes to a focus on a film back of the lens. When you take a picture, you must focus the camera. You can do this by moving the lens backward or forward. The closer the thing that is photographed is to the lens, the farther back from the lens will be the focus. You saw that this was true when you moved the candle in the experiment. But in a camera, you cannot move the film back and forth as you move the paper. So you move the lens instead. This does the same thing.

If you do an experiment, you can see that this is true. First, focus the lens so that a clear picture of the candle is made on the paper. Keep the

paper where it is but move the candle back a little. You will see that the picture is out of focus. Now move the lens until the picture is clear again. Did you have to move it toward the candle or away from it? Now you can see why you must focus most cameras to get a clear picture.

Some of the children in your school are probably using lenses to help them see better. Eyeglasses are lenses that bend light so that you can see more clearly. Perhaps you cannot see what is written on the blackboard unless you are very close. Or perhaps the words in your books do not look clear. If your eyes do not work properly, you can wear eyeglasses.

But a doctor should look at your eyes. He will tell you whether you need glasses and give you the right ones. Be sure to wear your glasses when you get them. And to help you most, your glasses must be kept clean.

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1. *What is the shape of the lens in a reading glass?*
2. *What does a lens do to light?*
3. *How is the picture that a lens makes different from the object?*
4. *Suppose that you want to make a picture on a screen larger. Would you move the object closer to the lens or farther from it?*
5. *Why do you have to focus a camera?*

How do we see things that are very small or far away?

While you were learning about germs, you read how Van Leeuwenhoek made the first microscope that could be used to see very tiny plants and animals. Without such a wonderful instrument, scientists could never have discovered how tiny plants and animals cause many diseases. And until scientists knew what caused the diseases, they could not find ways to fight them.

Of course, a microscope is not used just to study germs. Scientists use microscopes to discover many things about plants and animals. They have studied the tiny cells from which all living things are made. They know what happens when cells use food and grow. They even watch cells divide to make more cells. Without a microscope, no scientist would ever have seen any of these things. They are too small to be seen with the naked eye.

Look at the underside of a leaf with your naked eye. Then use a magnifying glass to look at it. A reading glass is a magnifying glass. You know that the lens is thicker in the middle than it is at the edge. It makes things look larger than they really are. Two lenses of this kind are used in a microscope. The lenses are placed at the ends of a tube. The tube can be made longer or shorter so that you can focus the microscope. Then you can see the object more clearly.

You know that scientists look at the moon, the planets, and the stars

through telescopes. One of the first telescopes was made by Galileo. He took an old organ pipe and put lenses in it. At one end was a lens that was thicker in the middle than at the edge. At the other end was a lens that was thicker at the edge than in the middle. From the top of a high tower, Galileo could see ships fifty miles out at sea.

The great British scientist, Sir Isaac Newton, made a different kind of telescope. At one end of a tube, he used a lens like the one in a reading glass. But at the other end, he put a metal mirror that was hollowed out in the center. This kind of telescope is called a reflecting telescope. Light from faraway objects strikes the curved mirror. From here, light is reflected to a flat mirror. Then it goes through a lens to your eye.

Both kinds of telescopes are used today. One kind has two different lenses. The largest telescope of this kind is at the Yerkes Observatory, Williams Bay, Wisconsin. The big lens is forty inches across. The other kind of telescope has two different mirrors and a lens. On Mount Wilson, near Pasadena, California, there is a reflecting telescope with a curved mirror 100 inches, or 8⅓ feet, across. Nearby, on Mount Palomar, there is an even larger telescope. This one has a mirror that is 200 inches, or 16⅔ feet, across. The picture on this page shows

With these field glasses, the girl can easily see a small bird high up in a tall tree.

part of this telescope. You can see how big it is by looking at the men who are working on it.

Have you ever looked through a pair of field glasses at a bird in a tree? Were you surprised at how clearly you could see it? If you look carefully at the field glasses, you will see that there is a glass lens at each end of both tubes. One tube is for each eye. The tubes are really little telescopes, side by side.

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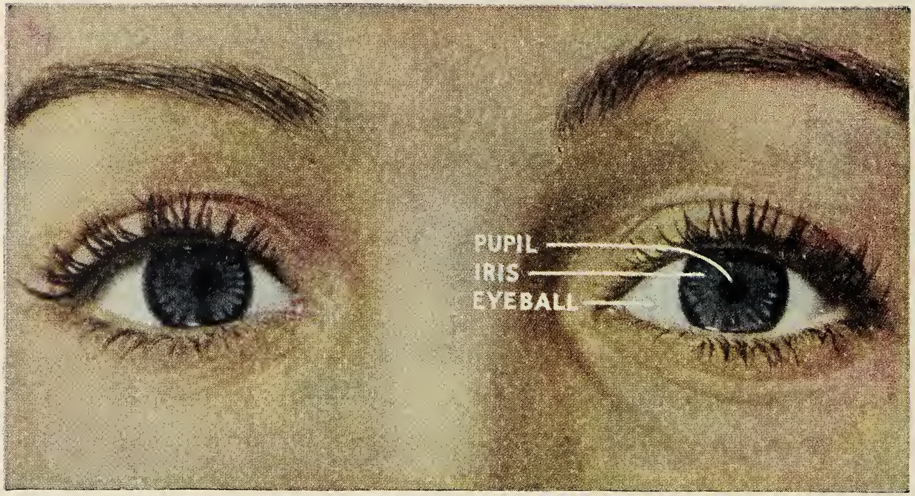
1. *Why was the invention of the microscope so important?*
2. *What are two kinds of telescopes that scientists use? What parts does each kind have?*
3. *How is a microscope different from a reading glass?*

How do we see things?

DID YOU EVER STOP and think how many different things you can see? You can see large things and small things. You can see things nearby and far away. You can tell what color something is. And you can see whether an object is moving toward you or away from you. You know how important your eyes are to you. But do you know how they work so that you can see things?

Look at the eyes of a person near you or look at your own eyes in a mirror. First, notice the black spot in



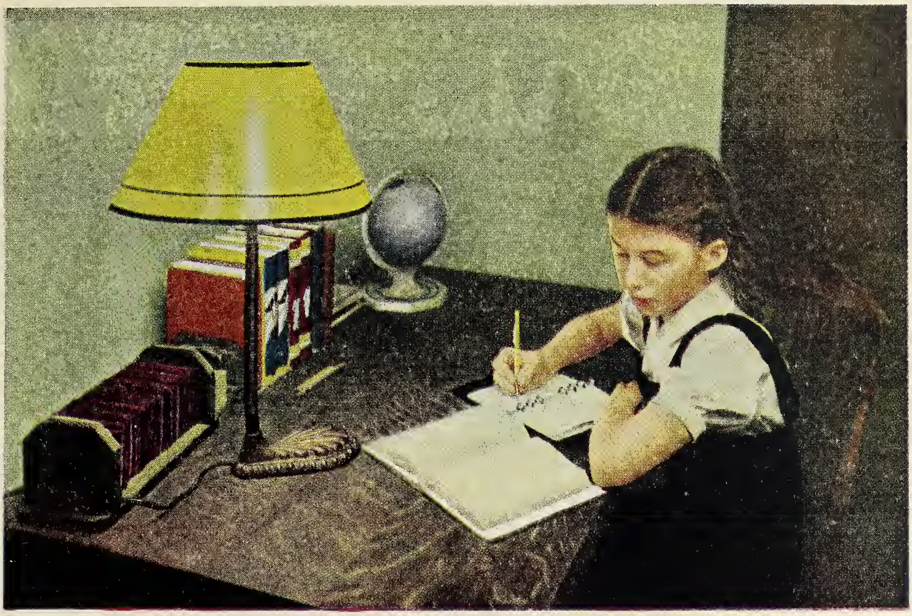
the center of each eye. This is really a little opening. It is called the pupil. Light shines through the transparent covering of the eye and then through the pupil. Next, look at the colored circle around the pupil. This circle is called the *iris.* In some eyes, the iris is blue. In others, it is brown, gray, or green.

The iris changes the size of the pupil. It is like a little curtain around the opening. It can make the pupil larger or smaller. Go outdoors into the bright light and then look at your eyes in a mirror. You will find that the iris has made the pupil small. This helps keep out some of the light. Then go into a dimly lighted room and look at your eyes in a mirror. You will see that the pupil is much larger. It lets more light into the eye. This helps you see when the light is dim.

Now look at the white of your eye. This covers the *eyeball,* as it is often called, because the eye is shaped almost like a ball. The eyeball is set in a hollow place, or socket, in the skull. The bones of the skull help protect it. Muscles hold the eyeball in the socket. These muscles move the eyeball so that you can see straight ahead, up, down, and to the sides.

Right behind the pupil is a lens that is thicker in the middle than at the edge. This lens bends the light that goes into your eye and brings it to a focus. The inside of the eyeball is covered with a very, very delicate lining, called the *retina.* It has many tiny nerves that carry messages to the brain when light strikes them.

Suppose that you look at a pencil. The pencil reflects light to your eyes. The light goes into your eyes through



When you have read these pages, tell whether you think this girl is using good light.

the pupils. Then it goes through the lens in each eye. The lens focuses the light on the retina. The light makes a picture of the pencil on the retina. This picture is carried by nerves to your brain. Your brain tells you that what you see is a pencil.

Your eyes have a great deal of work to do. When you read, write, walk, ride, sew, work with tools, or go to the "movies," your eyes are always looking. Think of the things that you have learned by using your eyes. It is easy to understand that your eyes are two of the most valuable things you own. It is also easy to understand how you can overwork your eyes. Many parts of your body are at rest during some part of the day. But your eyes are always at work except when your eyelids are closed.

Your eyes are very delicate, yet they must last all your life. What can you do to take care of them? First of all, be careful to use them in the best way you can. When your eyes work too long or too hard, the muscles and the nerves become tired. Then you have *eyestrain.*

You can strain your eyes by using them in a poor light. Light that is too bright is just as harmful as light that is too dim. You will strain your eyes if you read or do close work in either kind of light. In dim light, the iris cannot make the pupil big enough for you to see well. In very bright light, the iris cannot make the pupil small enough to keep too much light from getting in.

In the daytime, it is usually easy to see outdoors. Sunlight is a strong light. But when you come indoors, the light is not so strong. If you can, sit near a window when you read or do close work. Then you are less likely to get eyestrain. At night, you should use a bright light. But have a shade over the light bulb so that the light cannot shine straight into your eyes.

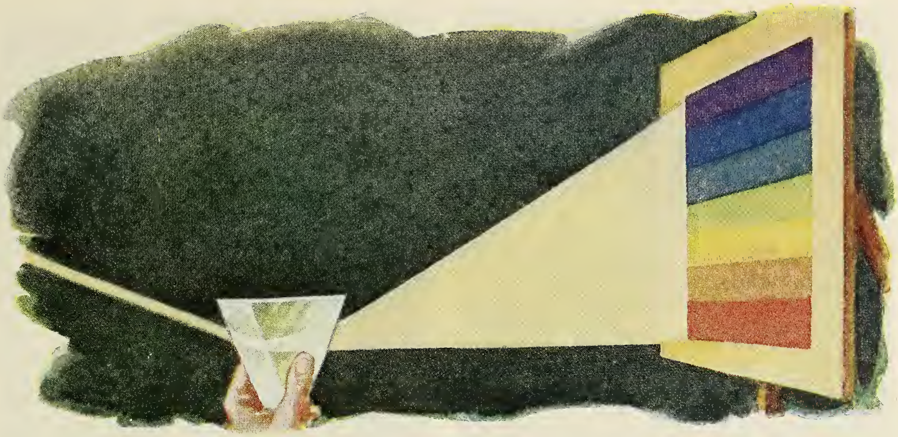
Did an automobile headlight ever shine into your eyes? If it did, you probably said, "I can hardly see. The light is blinding me." Never let the bright light of a lamp or the sun shine directly into your eyes. Light reflected from a shiny table, desk, or anything highly polished can also dazzle your eyes. Do not sit facing a window or other strong light.

Here is a list of safety rules for taking care of your eyes. Be sure that you understand the reason why you should obey each rule.

Safety rules for taking care of your eyes

1. In the daytime, sit near a window when you read or do close work.
2. At night, use a bright light but have a shade over the light bulb.
3. When you read, sit comfortably and hold your book fourteen to eighteen inches away from your eyes.
4. Rest your eyes from time to time by looking away from your book.
5. Never let the bright light of a lamp or the sun shine directly into your eyes.
6. Do not sit facing a window or other strong light.
7. Avoid using your eyes while you are getting over a serious disease.
8. Do not rub your eyes with your fingers. You may rub dirt into them.
9. Do not use another person's towel to wipe your face and eyes. There may be germs on the towel.
10. Have a doctor examine your eyes to see whether you need glasses.
11. Always wear your glasses if a doctor tells you to do so. Keep your glasses clean.
12. Be careful not to break your glasses. Do not do anything that might break another person's glasses.

1. *What does each of these parts of the eye do?*
   Pupil Retina Iris Muscles Socket Lens
2. *What things are likely to cause eyestrain?*
3. *How can you take good care of your eyes?*



Why do things have different colors?

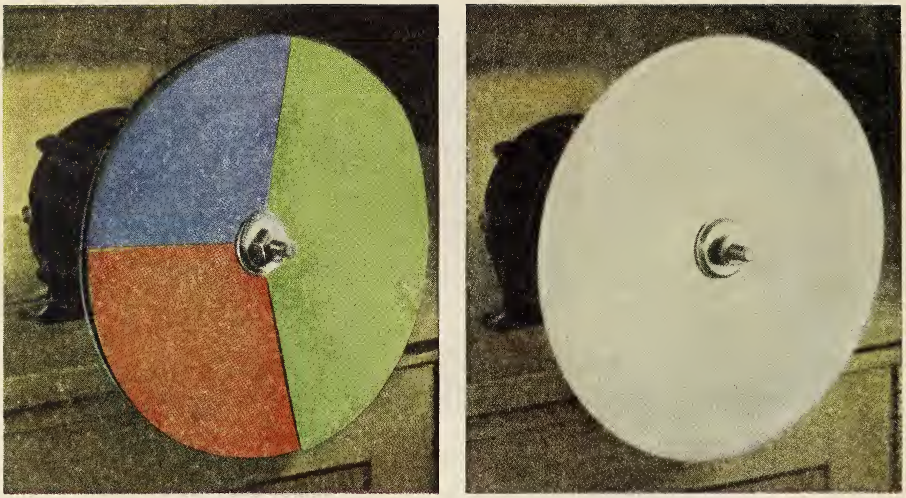
PROBABLY YOU ENJOY looking at things that have beautiful colors. Most of us like colorful leaves and stones, brightly colored flowers, brilliant sunsets, and colored birds and insects. Do you know why these things have colors? What causes color?

Perhaps you have heard your mother say, "Why, this dress looks entirely different at night. It isn't the same color as in the daytime." Or maybe when you were getting a new dress or suit, the salesman said, "Please step over here to the window. You can see the color better."

Surely, light must have something to do with color. You can do some experiments to find out what this is. First, get a glass *prism* like the one in the picture. Set the prism where direct sunlight shines on it. Have the light that goes through the prism fall on a piece of white paper. What do you see on the paper? Can you see red, orange, yellow, green, blue, and violet? What causes these different colors?

You know that they are not painted on the paper. Shut the sunlight away from the prism with your hand. Do you still see the colors? Now take away the prism and let the sunlight fall on the paper. Do you still see the colors?

The colors must have come from the sunlight that went through the prism. But sunlight looks white, as you know. How were different colors made from white light? Another experiment will help you find the answer to this question.



Divide a small circle of cardboard into three parts, as shown in the picture. Color each part with a crayon. Or cut out pieces of colored paper and paste them on the cardboard circle. One part should be red, one green, and one blue. Now fasten the colored circle on a top and spin the top. As the top spins, you cannot see red, green, and blue. If the top spins fast enough, the colors are mixed together. You see a grayish white. Scientists know that mixing all of the colors together makes white. So white is really a mixture of colors.

Now look carefully at the prism. Do you see that the sides are slanting? When light strikes a slanting side, it is bent. You can see this in the picture. The light is bent once when it goes into the prism and again when it comes out.

Each color of light is bent differently. Violet light is bent most, and red light is bent least. So the different colors in white sunlight separate as they go in and out of the prism. You can see that sunlight is really made up of several different colors. The light that goes into the prism is white. The prism bends some colors more than others. This separates the white light into its parts, and we can see the different colors.

Where else have you seen these colors? If you have ever seen a rainbow, you saw them in the sky. When there is a rainbow, something must bend sunlight and separate it into its colors. Can you tell what acts like a prism and does this? After a rain, there are often many tiny drops of water floating in the air. When sun shines through these drops of water, they bend the light and separate it into its colors. Now when you see a rainbow, you will know that drops of water in the air are separating sunlight into its colors.

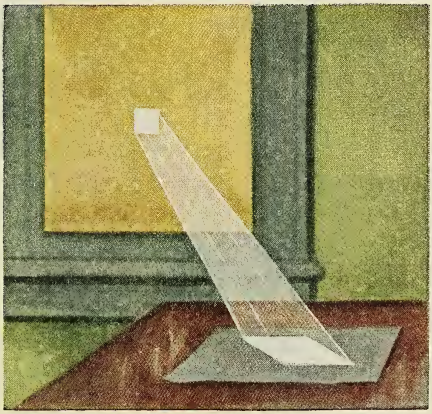
Have you ever seen a rainbow while you were using a hose to sprinkle a lawn? If you stand between the sun and the water, you can probably see a rainbow. Drops of water from the hose separate the sunlight into its colors.

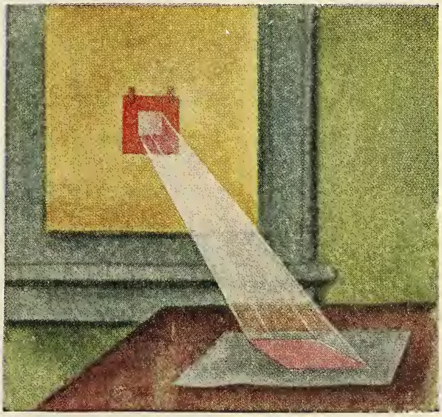
You have learned that white light is made up of several colors. You know that these colors can be separated from each other. But how does this explain why things have different colors? You saw that each color in sunlight can be separated from the others by bending it away from them. There is another way that the colors in light are separated. Let us see what it is.

When light strikes something, part of the light is absorbed and part of the light is reflected. The cover of this book absorbs part of the light and reflects part of it. Notice that the cover is blue. It looks blue because it reflects the blue part of the light. It absorbs all the other colors except blue. The blue light is reflected to your eyes, and the book looks blue to you.

Now look at a yellow pencil. The pencil reflects only the yellow part of light. It absorbs all the other colors. In the same way, a red dress looks red. It reflects only the red part of light. An orange reflects only the orange part of light. And green leaves reflect only the green part of light.

The color of anything really comes from the light that is reflected from it. Does this seem hard for you to believe? Try this experiment. Make a hole about an inch square in a piece of brown wrapping paper. Pin the paper over a window through which the sun is shining. Have the light that





comes through the hole fall on a piece of white paper. Of course, the paper looks white where sunlight falls on it. The white sunlight is reflected to your eyes.

Now hold a piece of red glass or red cellophane over the hole. What color is the spot of light on the paper? The red glass or cellophane lets only red light shine through it. So only the red light falls on the paper. This light is reflected to your eyes, and the spot of light on the paper looks red. If you can, try the experiment again with green and blue glass or cellophane. What color will the spot of light be?

What happens in this experiment is somewhat like what happens when light is reflected from a material. When a material looks red, the parts of the light that are not red are absorbed. Only the red part is reflected. When sunlight falls on the white paper, the paper does not reflect just one of the colors that are in sunlight. It reflects all the colors. So the paper looks white. Anything that looks really white reflects all the light that strikes it.

If you look into a deep, narrow hole or a dark closet, it looks black inside. You cannot see anything because no light is reflected to your eyes. Instead, the light is absorbed. An object that is really black reflects no light at all. You can see a black object only because other objects around it reflect light.

Scientists say that black is not a color. It absorbs all colors, and it reflects none of them. So black is really a lack of color. Scientists say that white is not a color, either. It reflects all colors, and it absorbs none of them. So white is really a mixture of the colors that make up white light.

1. *How does a prism separate the colors of the rainbow from sunlight?*
2. *Explain why the cover of this book looks blue.*
3. *Why does sunlight shining through a piece of red glass make a red spot on white paper?*
4. *What must you have to make a rainbow? Why?*
5. *What have you learned to make you believe that sunlight is really a mixture of different colors?*

QUESTIONS TO ANSWER

1. Why can you see things more clearly through a clean window than through a dirty one?

2. What are some of the ways in which lenses are useful to scientists in their work?

3. Lights are often used to change the colors of the actors' costumes in a theater. How do you think this is done?

4. The sun is about 93 million miles from the earth. How long does it take sunlight to reach us?

5. A piece of cloth that is red in sunlight looks black if light shines on it through green glass. Explain why this is true.

6. What things in your schoolroom help make the lighting good?

7. If you are reading at home, how can you get the light you need?

8. How is your eye like a camera? Do you think that the picture which your eye takes is upside down? Explain your answer.

9. Why do scientists say that black and white are not really colors?

THINGS TO DO

1. If you have ever looked through a microscope or a telescope, tell your class what you saw that you could not see with your naked eye.

2. Look at some road signs and find out how they reflect light at night.

3. Find as many instruments that use lenses as you can.

4. Doctors and dentists use curved mirrors to look into a person's mouth or throat. Find out what these mirrors do to light.

5. Make a collection of opaque, transparent, and translucent materials. Test each material with a flashlight to see whether light goes through it.

6. Find out how the silvery material is put on the backs of mirrors.

7. Learn what the different shapes of lenses are called.

8. Examine the headlights of an automobile. Find out how they shine the light ahead of the car.

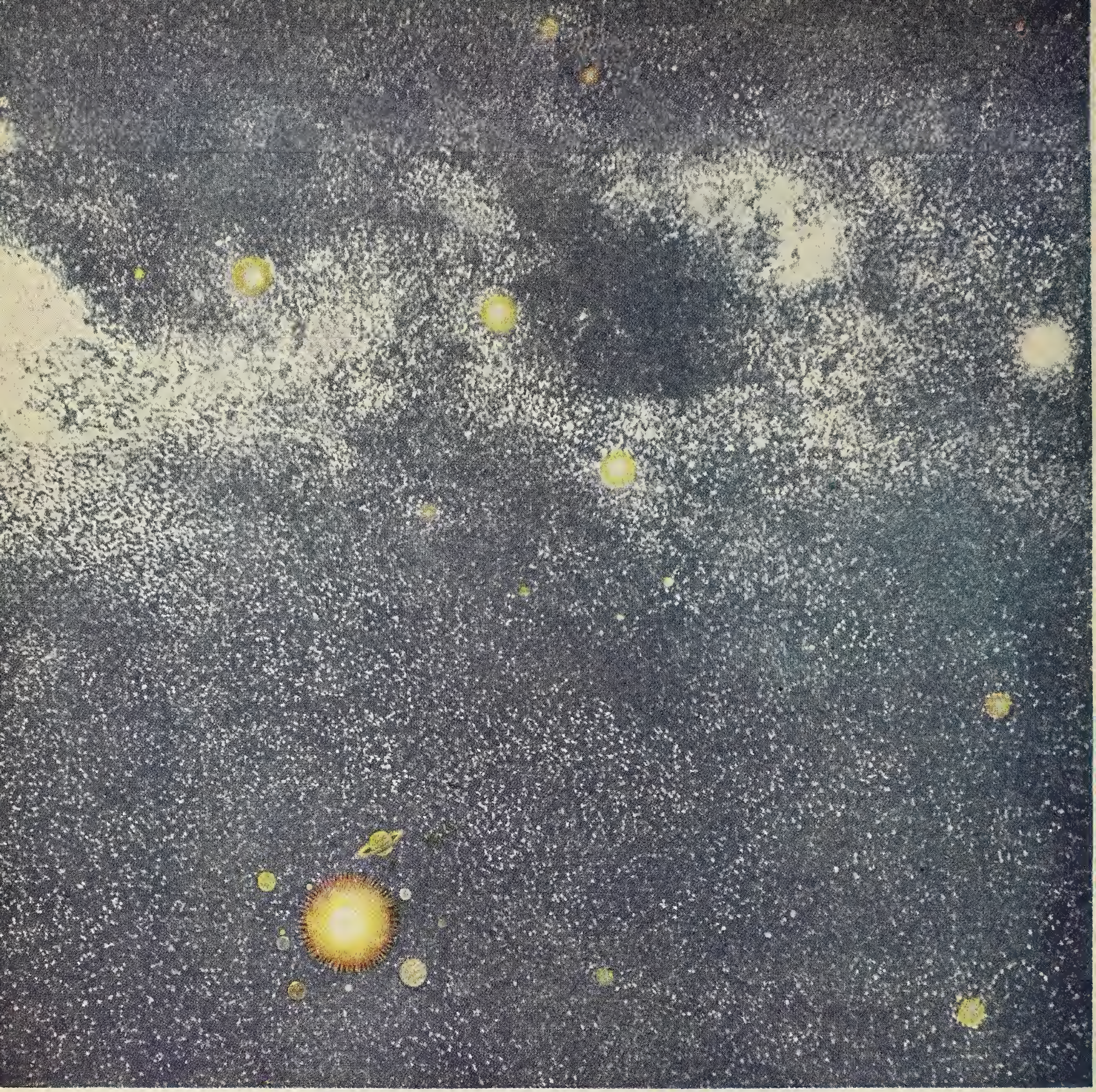
9. Get a reading glass that has a thicker or thinner lens than the one you used in the experiments on pages 172 and 173. Then do the experiments over again with this lens. What happens to the focus? Is it closer to or farther from the lens?

10. Find out about the eyes of these animals—oyster, mole, fly, bird, cat, owl, whale.

11. Blow soap bubbles and see the colors in them.

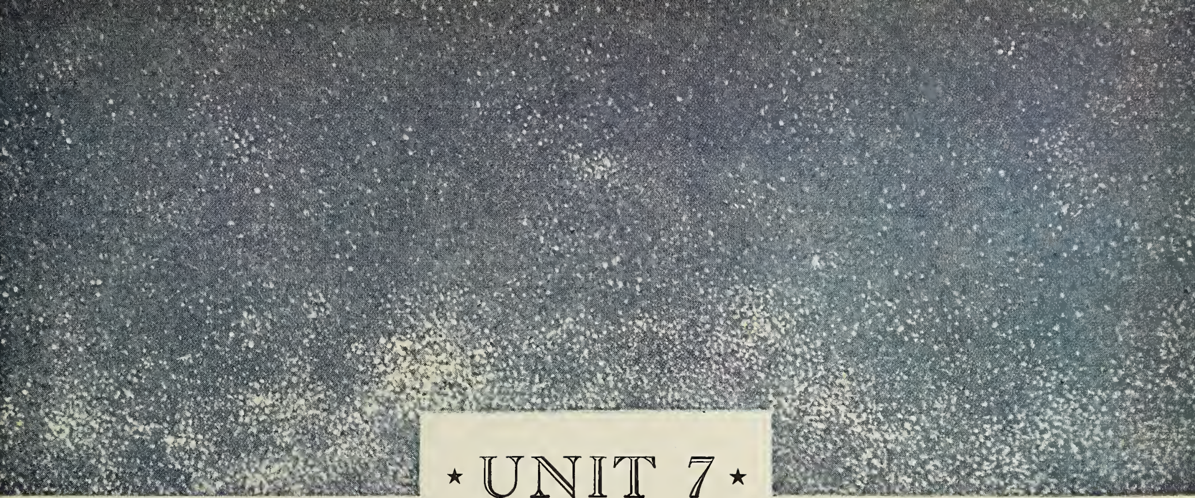
12. Visit a clothing store and find out how three mirrors are arranged so that you can see yourself better.

13. Find out how a doctor uses an eye chart to test a person's eyes.



⋆ *In Unit Seven You Will Learn* ⋆

⋆ *How the sun helps us* ⋆ *How the planets move in the solar system* ⋆
⋆ *What scientists have learned about the planets* ⋆
⋆ *What comets are* ⋆ *What causes an eclipse* ⋆
⋆ *What is beyond the solar system* ⋆



UNIT 7

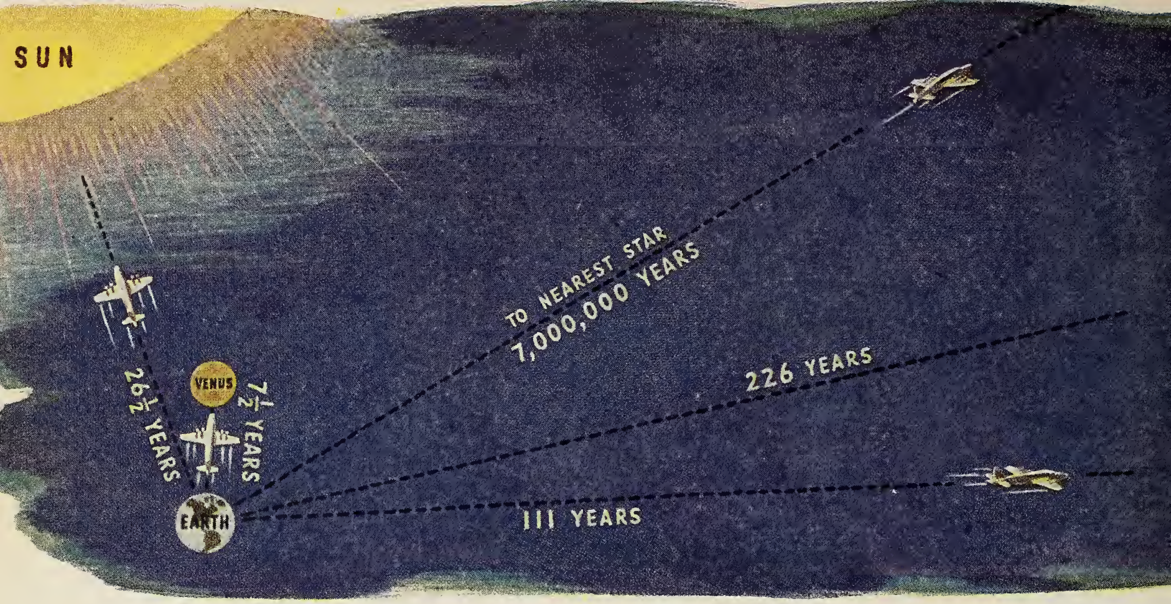
What Is the Universe Like?

Did you ever hear the story of how Columbus once got food from the Indians? Even though his men were starving, the Indians would not give them anything to eat. So Columbus decided to play a trick on the Indians. As you probably know, Columbus was a very good sailor. He had learned a great deal about how the earth, the moon, and the stars move. His charts showed him that there would be an *eclipse* of the moon on March 1, 1504.

During an eclipse, the light from the moon is slowly blotted out. A round, black shadow moves across the moon. Columbus knew that this would happen. So, a few days before March 1, he warned the Indians that he would make the moon disappear unless they gave his men something to eat. Of course, the Indians did not believe that he could do it. So they still would not give him any food for his men.

Then came the night of March 1. Slowly a black shadow began to creep across the moon. It got darker and darker. The Indians were frightened. They ran to Columbus and begged him to bring the moon back. They promised to give him food or anything else that he wanted if he would only do this. Columbus agreed, and soon the shadow was gone. The moon was as bright as ever. Columbus knew that this would happen. His trick saved his men from starving to death.

Of course, you will never need to use what you learn about the things in the sky in the same way that Columbus did. But some day you may want to fly an airplane or sail a boat. Then you will have to find out many things about the moon, the stars, and the planets. Right now, you probably



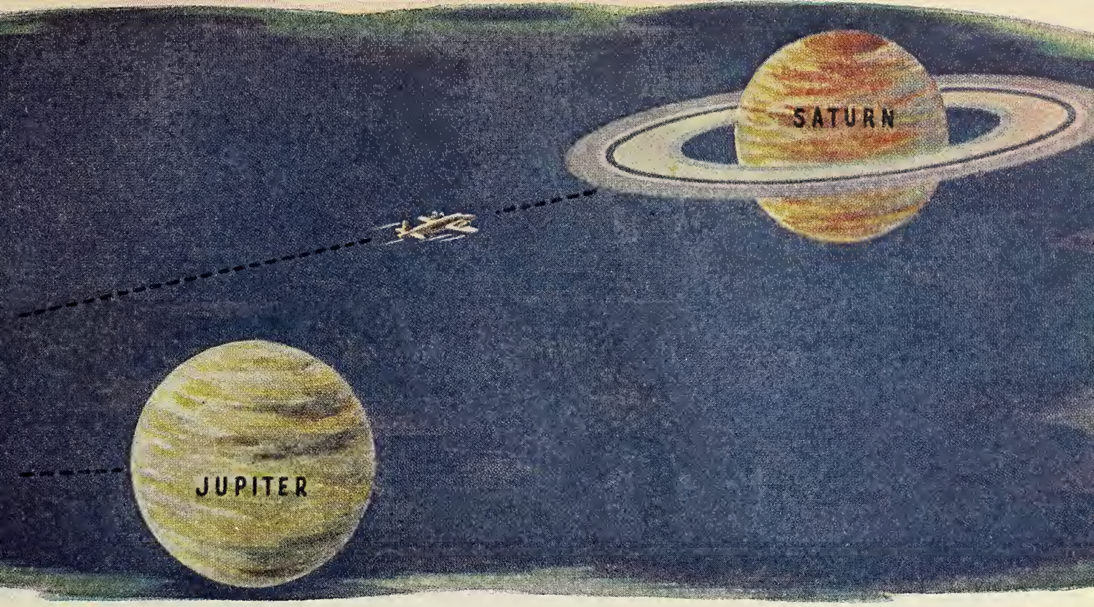
Suppose that an airplane travels through space at 400 miles an hour, as the drawing on these two pages shows. How long would it take to go to the sun, to Venus, to Saturn, to Jupiter, to the nearest star other than the sun?

have some questions about what happens in the sky. As you study this unit, you will find the answers to many of your questions.

You already know about some of the things that you can see in the sky. Suppose that you think about what you have learned. First, you will probably think of the sun. The sun is a huge ball of glowing gases that gives us heat and light. As you know, the sun is a star. Next, you may think of the sun's "family." The earth and the other planets belong to this family. They never leave the sun. Year after year, they revolve around it, each in its own path. Some planets take much longer to go around the sun than the earth does.

Then you may think of the earth's moon. Most of the other planets have moons, too. All the moons travel around the sun along with the planets. Scientists have a name for the sun, the planets, the moons, and the other things that travel around the sun. They call this whole family of things the *solar system*, which means sun system. Our planet is part of the solar system.

Far out beyond the planets are the stars. With your naked eyes, you can probably see about 5000 of them. But telescopes show that there are thousands of millions of stars. None of these stars travels around our own star, the sun. So, of course, they do not belong to the solar system. They



are part of a much larger system that includes everything in the sky. This system is called the *universe*. In this unit, you will learn about the universe and some of the things that happen in it.

How does the sun help us?

NEAR THE MIDDLE of the solar system is the star we call the sun. The earth is about 93 million miles from this huge ball of hot, glowing gases. On a hot summer day, it is probably hard for you to believe that the sun is so far away from the earth. You can easily write 93 million miles. But what does this distance mean to you? It is more than 3700 times the distance around the earth. This is too far for anyone to have a real idea of it. Yet this great distance is very small when it is compared with other distances in the universe. So you will have to stretch your imagination while you are studying this unit.

Do you know what would happen if the sun suddenly stopped shining? Here is a story that will tell you. Of course, this story is only imaginary. But when you read it, you will learn what would happen if the sun stopped shining. This is the story.

"So far as I know, I am the only person living on earth today. Perhaps sometime in the far-off future, other people may again live on the earth. So I am writing this story to tell those people what became of us.

"My story begins one warm night in June. I went to bed as usual. Several times during the night, I woke up and found that it was still dark.

The night seemed so very long that at last I looked at my watch. The hands pointed to almost twelve o'clock. At first, I thought it was nearly midnight. But I was sure that I had been in bed more than a few hours. Just then, I heard people talking outside my window. They were very excited. So I went out to see what was going on.

"Everyone felt that something terrible had happened. We knew that it must be morning. In fact, it was almost noon. Yet there was no sun in the sky. We knew that the sky was clear, because we could see the stars. You cannot imagine how we felt. How would you feel to wake up some noon and find it pitch-dark instead of daylight?

"Of course, we turned on the electric lights in our homes, and the city turned on the street lights. Most of us thought that we could go on about our business as usual, and we did. We did not notice anything different from the day before except that there was no light or heat from the sun. That night, I went to bed at my usual time. But I set my alarm clock, because there would be no sunlight to tell me that daytime had come.

"During the night, it began to get colder. I put a heavy blanket over me. The next few days grew colder and colder until we had to wear our winter coats. At last, we lost track of time because there was no difference between day and night. When there had been daylight and darkness every twenty-four hours, it had been easy to tell ten o'clock in the morning from ten o'clock at night. But soon we could not tell the time of day or the day of the week or of the month.

"I had read how the Indians used to keep a record of the months by watching the moon. But now there was no moon to be seen. We could not see the moon, because the sun had stopped shining. For the first time in my life, I was sure that moonlight was really reflected sunlight. The stars were unusually bright, though. We could see them in the sky all the time.

"Of course, I knew that green leaves must have sunlight to make food. But I was surprised to see how quickly plants in my garden died without light. I went to the grocery store to get as many cans of vegetables and fruits as I could. The grocer would sell only a few cans to each person. Never before had I realized that canned fruits and vegetables were really 'canned sunshine.'

"One day, the milkman did not bring the milk. The grass in the pastures had died, and the supply of hay and corn from the year before had all been used up. Luckily, there was plenty of meat. But I soon learned why. The farmers were killing their cows, sheep, pigs, and chickens because there was nothing to feed them. I knew that meat would soon be gone, too. Many animals were dying because they had no green plants to eat.

Why could there be no stacks of wheat or fields of corn if the sun did not shine?

I found several rabbits and squirrels and many birds and insects lying dead on the ground.

"Meanwhile, it was getting colder and colder all the time. One day, no water came when I turned on the faucet. At first, I thought there was something wrong with the water pipes. But I found that the water in the city reservoir was frozen solid.

"One day, I put the last coal that I had into the furnace. As I shoveled it in, I was using another kind of canned sunshine. Coal is what is left from green plants that grew in the sunshine millions of years ago. When the coal was gone, I shut up most of my house and moved into the kitchen. We still had gas and electric current, but no one knew how long they would last.

"I was warned to use my electrical appliances as little as possible. Our city got its current from a powerhouse that used coal to make steam for running the generators. With so much coal being used to keep people warm, I knew that the supply would soon be gone. Moving water could no longer be used to run generators, because the water in all the streams was frozen.

"Soon the trains and streetcars stopped running. The radio and the telephone were silent. There were no newspapers. We had no way to tell what was going on in the rest of the world. But I thought there might be

Millions of years ago, plants like these used the energy of the sun for growing and making food. When these plants died, they were buried in the earth and changed to coal.

some place on earth where life was going on as before. I was glad that I had spent my spare time in learning to fly an airplane. At least, I could try to escape from sure death here at home.

"This seemed easy until my plane started to leave the ground. Then I quickly realized how much I depended on light to get into the air safely. How I managed to get my plane off the ground I will never know. Of course, I could not see the earth at all. There were no lights anywhere except in the sky. These lights were the stars. I found the North Star, which showed me where north was. Then I headed my plane east.

"After many hours in the air, I heard the engine sputter. The plane was running out of gasoline, and I knew that I must land. So I dropped a flare. Luckily, I saw a bare field below me. By the light of the flare, I could also see a small town near the field. After I landed, I took my flashlight and walked to the town. I saw not one living thing. I shouted and called, but no one answered. Then a terrible thought came to me like a flash. Perhaps I was the only person left alive on earth. Without the sun, nothing could stay alive very long."

Of course, you know that this story is just imaginary. Scientists tell us that the sun will keep on giving heat and light for millions and millions of years. But this story will help you understand why we need the sun. Without its help, we would have no

The coal that these miners are digging was made from the plants that lived millions of years ago. When we burn the coal, we are using the energy of the sun that the plants used for growing so many years ago.

heat or light. There would be no food, either, because green plants must have sunlight to grow and make food. Nothing could live on the earth without heat and light from the sun.

In our world, most of the work is done by energy from the sun. Wind gets its energy when the sun heats the earth and the air above it. If all the water were frozen, there would be no energy of moving water. The energy stored in coal and oil came from plants that grew millions of years ago. You can see how much the sun means to us and every living thing on earth.

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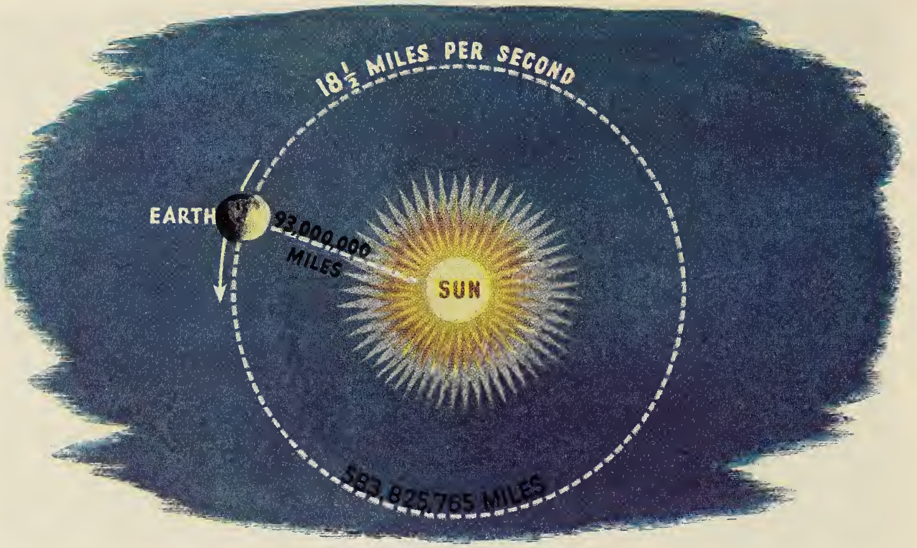
1. *The story told you many ways in which the earth would be different if the sun stopped shining. Name as many of these ways as you can.*
2. *Make a list of the ways in which the sun helps us.*
3. *Do you think that the sun will soon stop shining? Why?*
4. *The energy in your muscles really comes from the sun. Explain why this is true.*



How do the planets move in the solar system?

Maybe you have ridden in an automobile, a train, or even an airplane that traveled very fast. You may have gone 60 miles an hour in an automobile, 90 miles an hour on a train, or 300 miles an hour in an airplane. You may think such speeds are very fast, but you are going much faster right now. Do you know why this is true?

As you sit quietly at your desk and read this page, you are traveling 66,000 miles an hour! Every second you are whizzing through 18½ miles. By the time you count to ten, you will have gone nearly 200 miles. The earth is going at this terrific speed as it travels around the sun. Yet you do not need to be afraid of falling off the earth. The force of gravity holds you on. You could not jump off the earth even if you tried. Of course, you can jump into the air a few feet. But you know that gravity pulls you right down again.

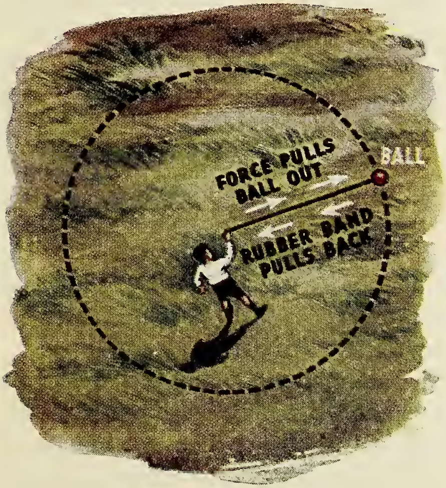
Perhaps you are wondering why you do not feel this great speed. When you are traveling fast in an automobile or a train, you can see trees, houses, and telephone poles pass quickly by. You learn to tell about how fast you are going by watching how fast you pass nearby objects. But there is nothing near the earth to tell you how fast the earth is moving. The nearest neighbor of the earth is the moon, and it is about 240,000 miles away. You do not realize that you are moving, because you cannot see anything pass by.

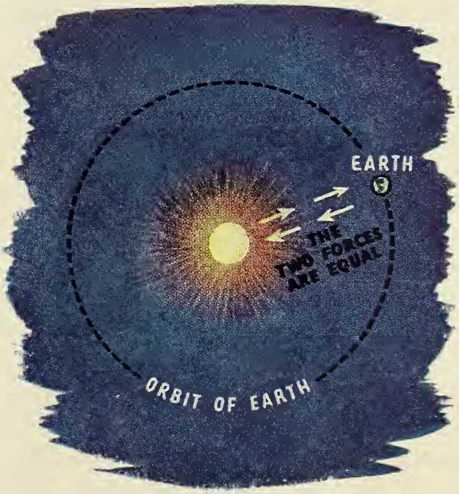
Traveling at high speed may be very dangerous. But you do not need to be afraid of the earth's great speed. The earth keeps in its same path around the sun year after year. It will not crash into anything. Each year, it takes the same long journey around the sun. And year after year, it revolves in the same path at the same speed.

You can do an experiment to find out how the earth keeps in the same path around the sun. Get a ball and fasten a strong rubber band to it. Hold on to one end of the rubber band. Now whirl the ball round and round over your head. The harder you whirl it, the farther out the ball goes. At last, it will go no farther. Notice how the ball travels. As long as it is going at the same speed, the ball stays in the same path. It also stays at the same distance from your head.

As you whirl the ball, a force pulls the ball away from your hand. You can feel this force pulling on your hand. At the same time, the rubber band is pulling the ball in toward your hand. If you stop whirling the ball, this force pulls it back toward you. So there are two forces pulling on the ball. One pulls the ball out, and the other pulls it in. When the force that pulls the ball out is just equal to the force that pulls it in, the ball does not move out any farther. It keeps on whirling in the same path.

Now how does the whirling ball help explain why the earth always moves in the same path? As the earth travels around the sun, a force is pulling it away from the sun. This is the





same force that makes any whirling object pull away from the center around which it whirls. There is also another force that is pulling on the earth. It pulls the earth toward the sun as the rubber band pulls the ball. This force is gravity. The force of gravity pulls the earth toward the sun just as it pulls you and other things toward the earth.

The earth stays in the same path because these two forces are equal. This path is about 93 million miles away from the sun. Round and round the earth goes. It is held in its path by these two forces. Scientists call this path around the sun an *orbit*. The earth's orbit is nearly a circle.

Scientists have found nine planets that revolve around the sun. You know that the earth is one of these nine planets. Two of the planets are nearer to the sun than the earth is, and six are farther away. Each planet travels in its own orbit around the sun. The planets cannot run into each other, because each one is held in its own path. The nine planets all revolve in the same direction.

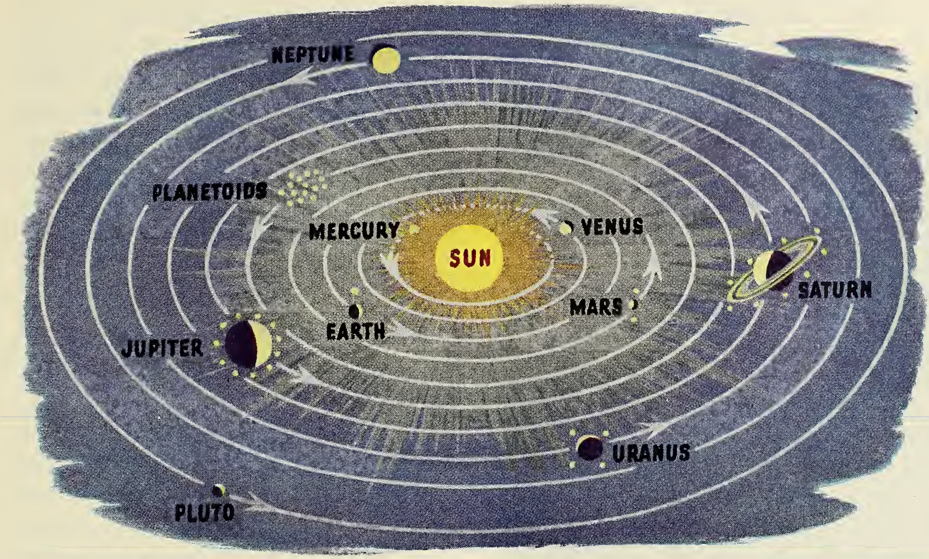
Do you know how large the solar system is? It is almost 7½ billion miles across! You could think of the solar system as a huge phonograph record with a big ball at the center. This ball would be the sun. Then around the ball there would be nine smaller balls. These would be the planets. Each one would be whirling in its own circle around the sun.

You know that the sun and the planets are not the only things in the solar system. Most of the planets have at least one moon, and some of them have several moons. Each moon travels in its own path about its planet as the planet goes around the sun. And each moon is held in its orbit by the same forces that hold the planets in their orbits. There are some other things in the solar system besides the planets and their moons. You will learn about them later in this unit.

Of course, you remember that the planets are not stars. Stars are huge balls of hot, glowing gases like the sun. Stars shine with their own light, because they are so hot. The planets are very small when they are compared with the sun or other stars. They do not shine with their own light. A planet is seen in just the same way that a house is seen. Light from the sun strikes it, and it reflects this light to your eyes.

You remember that the earth spins on its axis. The axis is an imaginary line through the center of the earth. One end of the axis is the North Pole, and the other end is the South Pole. The earth rotates on its axis. As it turns completely around every twenty-four hours, we have daylight and darkness. Each planet rotates on its axis as it revolves around the sun.

The earth rotates on its axis more steadily than any machine that we can make. No one has ever made a clock that keeps time so well, year in



The planetoids are a group of small objects like tiny planets that travel around the sun in their own orbits. Look at the picture on page 202 to see how the planets compare in size with each other and with the sun.

and year out, as the earth spinning on its axis. It turns at the same speed, year after year.

All the planets move in their own orbits around the sun. They move so steadily that scientists know exactly where any planet is at any time. The scientists can point their telescopes at that place in the sky and always find the planet there. The solar system is like a huge machine that keeps on moving in the same way and never stops.

People have sometimes been afraid that the earth would bump into another planet and be destroyed. Scientists know that this cannot happen. Each planet revolves in its own orbit. It is held there by the same forces that keep the earth in its orbit.

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1. *What is near the middle of the solar system?*
2. *Why can we see the planets?*
3. *Explain how the earth stays in its orbit.*
4. *Name as many ways as you can in which the planets are alike.*
5. *Tell what you have learned about each of these.*

   Orbit *Axis* *Gravity* *Solar system*

What have scientists learned about the planets?

ALL THE PLANETS except the earth were named for the gods and goddesses in old stories. In these stories, Mercury was the swift messenger of the gods. So the planet that moves the swiftest is called Mercury. It travels at the great speed of nearly 30 miles a second! That is over 100,000 miles an hour! In less than three months, Mercury travels all the way around the sun.

Mercury is hard to see because it stays so close to the sun. But sometimes just after sunset, you can see Mercury in the western sky. Scientists are sure that there is no air or water on this planet. Could there be any living things on Mercury? Why do you think so?

Venus is the brightest planet. It looks brighter than anything else in the sky except the sun and the moon. It was called Venus because it is so beautiful. In old stories, Venus was the goddess of beauty. You often see Venus as the "evening star" or the "morning star." Of course, Venus is not a star at all. It is a planet that is almost as big as the earth. Sometimes Venus is called the earth's twin, because the two planets are about the same size. It takes Venus 225 days to go around the sun.

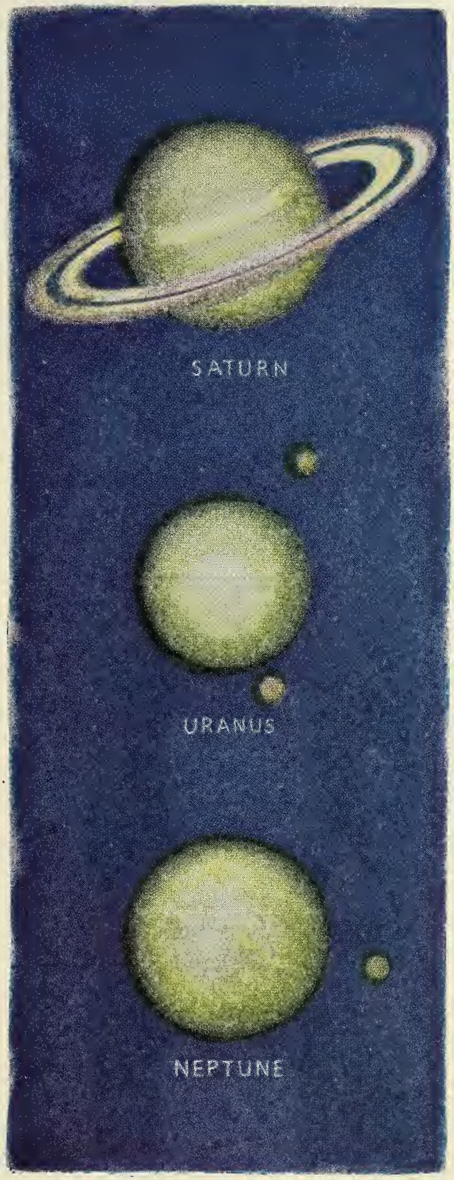
If you could look at Venus through a telescope, you would see that thick clouds are all around it. Venus comes closer to the earth than any other planet. But we cannot see its surface because of these clouds. Perhaps Venus may have living things on it. Scientists cannot find out whether it has or not.

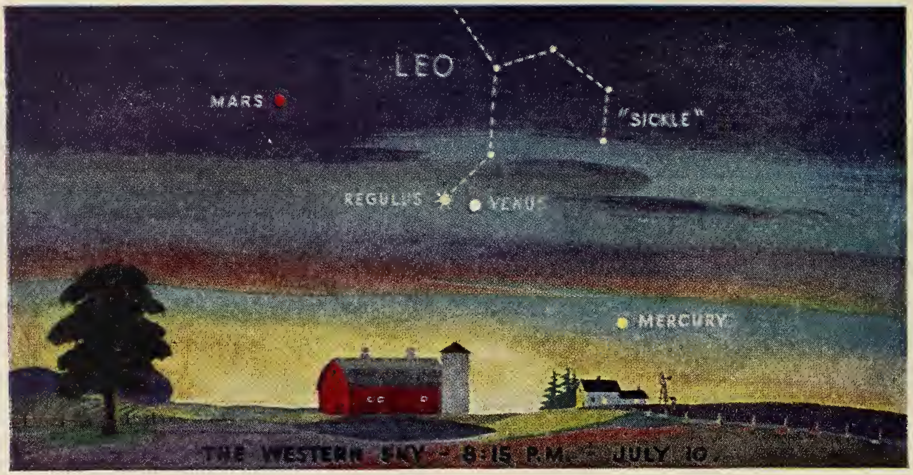
The planet Mars got its name because it looks red. The god of war was called Mars. So the planet was named for the god who caused bloodshed. Scientists know more about Mars than they do about any other planet. Mars has two moons. It is much smaller than the earth, but a day on Mars is just about as long as our day.

There are seasons on Mars just as there are on the earth. But the seasons on Mars are longer than ours. A year on Mars is nearly twice as long as a year on the earth, because it takes Mars almost twice as long to travel around the sun. Mars is farther from the sun than the earth is. So Mars is colder than the earth.

There is very little water on Mars. It does not seem to have oceans or seas. Much of it is probably a dry desert. The air on Mars is very thin. It is somewhat like the air on a high mountain on the earth. Mars could have living things on it, because it has both air and water. But scientists are not sure whether there are living things on it or not, although some think that there may be plants.

Through a telescope, Mars looks like a red ball with lines on it. Some people think that these lines may be ditches or canals. If that is what they are, they might have been made by people. No one knows whether this





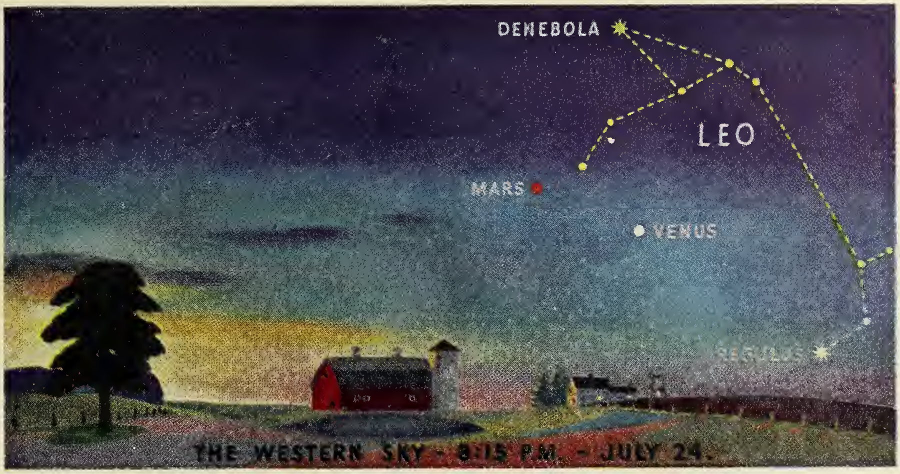
Look at this picture carefully. Notice the positions of Regulus and the other stars and of the planets.

is true. In the spring, Mars has bluish-green patches on it. In the autumn, these patches turn brown. If green plants were growing on Mars, they would be green in the spring and brown in the autumn like the green plants on the earth. The latest photographs of Mars seem to show that there may really be plants on it.

The giant planet Jupiter was named for the king of the gods. Jupiter is larger than all the other planets put together. It turns completely around on its axis once in about ten hours. So its day is only ten hours long. But a year on Jupiter is nearly as long as twelve of our years. Jupiter is almost as bright as Venus. It usually looks much brighter than any star. Like Venus, Jupiter is sometimes called the "morning star" or the "evening star." Of course, it is not really a star.

If you could look at Jupiter through a telescope, you would see that it has thick clouds around it just as Venus does. These clouds look like belts around the planet. Jupiter has eleven moons. With his telescope, Galileo was the first scientist to see some of these moons. Two of the moons were discovered not many years ago.

Saturn is a very unusual planet. If you ever get a chance to look at it through a telescope, you will see a sight that you will never forget. You may think that Saturn is the most beautiful planet. It is different from the others, because it has three huge rings around it. These rings are made of millions of tiny objects. They move around Saturn in a thin sheet. There is a dark ring close to the planet, and two bright rings with a space between them. Galileo was the first person to



Now look at the same place in the sky two weeks later. Why do the stars seem to have moved? Have the planets moved? How do you know?

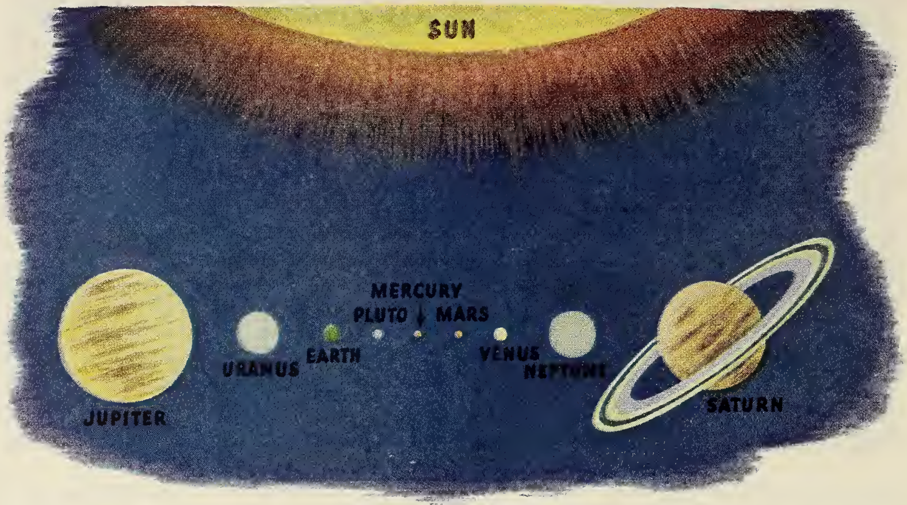
see Saturn's rings. Saturn also has nine moons out beyond the rings. A year on Saturn is about as long as thirty of our years.

The planet Uranus is so far away from the earth that it can hardly be seen with the naked eye. The earth makes eighty-four trips around the sun while Uranus is making just one. So the year on Uranus is as long as eighty-four of our years. The planet turns on its axis so fast that it takes only about eleven hours to turn once around. Uranus has five moons. Sir William Herschel, a British scientist, discovered Uranus about 165 years ago. He was trying out a new telescope he had made, and he found the planet by accident.

Neptune is so very far away from the earth that it cannot be seen with the naked eye. It was named for the god of the sea, who was Jupiter's brother. It takes Neptune almost 165 years to go around the sun once. So its year is nearly as long as 165 of our years.

About 100 years ago, scientists discovered Neptune in a very interesting way. As they were watching Uranus, they found that it was not following the path they thought it should. One scientist suggested that there might be another planet out beyond Uranus that was pulling it away from its orbit. Then several other scientists spent months figuring out where such a planet would be. When a telescope was pointed at this place, there the planet Neptune was!

A little over fifteen years ago, another planet was discovered. It was named Pluto for the god of the underworld. Pluto is about forty times



You can see that the earth is one of the smaller planets. But even Jupiter seems small when it is compared with the sun.

as far from the sun as the earth is. It can be seen only with a very powerful telescope. Scientists have not yet learned much about this planet. Some of them think that there may be other planets beyond Pluto. Perhaps you will read about their discovery someday.

In the table on the next page, you will find some of the things that scientists have learned about the planets. At the top of each column of the table, there are several words that tell you what you will find in that column. At the left is the name of each planet. Suppose that you want to find out how big Mercury is. Look on the same line as *Mercury* in the column marked *Size*. How big is Mercury? Is it larger or smaller than the earth? How can you tell?

From this table, you can see that there is one planet about the same size as the earth. And you can see that there are two smaller planets. What planet is about the same size as the earth? Which planets are smaller? Which planets are larger than the earth?

To find how far Venus is from the sun, look on the same line as *Venus* in the column marked *Distance from the Sun*. Do you find that Venus is 67 million miles from the sun? Which planet is the nearest to the sun? Which one is farthest away?

Now study the table to find out how long it takes the different planets to revolve around the sun. How many days does it take Mercury to go once around its orbit? How many times does Mercury go around the sun while

NAME OF THE PLANET	SIZE (DIAMETER IN MILES)	DISTANCE FROM THE SUN IN MILES	TIME IT TAKES TO TRAVEL AROUND THE SUN	SPEED IN MILES PER SECOND	NUMBER OF MOONS
		Millions	*Days*		
Mercury	3,000	36	88	29.7	0
Venus	7,700	67	225	21.7	0
Earth	8,000	93	365¼	18.5	1
Mars	4,300	142	687	15.0	2
			Years		
Jupiter	88,400	483	11.8	8.0	11
Saturn	74,150	886	29.5	6.0	9 (3 rings)
Uranus	30,200	1,782	84.0	4.2	5
Neptune	34,800	2,793	164.5	3.4	1
Pluto	6,000	3,675	247.7	2.9	?

the earth is going around the sun once? How fast does Mercury travel? How fast does Neptune travel?

If you look in the column marked *Number of Moons,* you will find that Mercury and Venus have no moons. Which planet has eleven moons? Which ones have only one moon? In the line where Pluto is, you will find a question mark. They show that scientists do not yet know whether this planet has moons or not.

Have you ever heard radio programs or read stories about people from the earth going to other planets in rocket ships? Or have you read stories about people from other planets landing on the earth? Some of these stories tell about people from Mars coming to the earth to destroy us. Of course, you know that these stories are not true. So you will not be frightened by them. You can enjoy them just as you do any other imaginary story.

Scientists have made rockets that went up more than 100 miles above the earth. But that is not very far compared with the distance to the nearest planets or even the moon. No one has ever made a trip to another planet or to the moon. But not long ago, scientists were able to send a signal to the moon by radar. On the next page is a picture of the queer-looking tower they used to send out a kind of electrical wave. These waves traveled out to the moon. They struck the moon and bounced back, as sound waves do when they bounce back and make an echo. This is the only kind of message that has ever been sent to the moon.

When you read imaginary stories about people from Mars or other planets, you may find that it is fun to try this plan. After you have finished the story, make a list of all the things you have just learned about the planets that show you why the story could not be true.

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1. *Which planet do scientists know most about? Why?*
2. *Which planets can be seen from the earth with the naked eye?*
3. *Which planets did scientists discover by using telescopes?*
4. *Choose one planet and tell everything you have learned about it.*
5. *Which planets might have living things on them? Explain why it might be possible for things to live there.*
6. *Name three ways in which Venus and Jupiter are alike. Then give three ways in which they are different.*
7. *Look at the table on page 203. Which move faster, planets near the sun or planets far away from it? Which ones have longer years?*

What are comets?

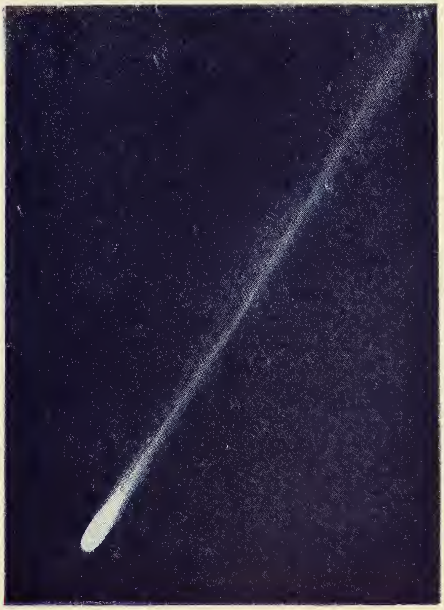
For hundreds of years, people have watched the moon, the planets, and the stars. Now and then, they were frightened by something else they saw in the sky. As it came nearer and nearer, it got brighter and brighter. People feared that it might hit the earth. It did not look like other things in the sky. It often had a long tail, or streak of light, behind it. Scientists know that this strange thing is really a *comet.*

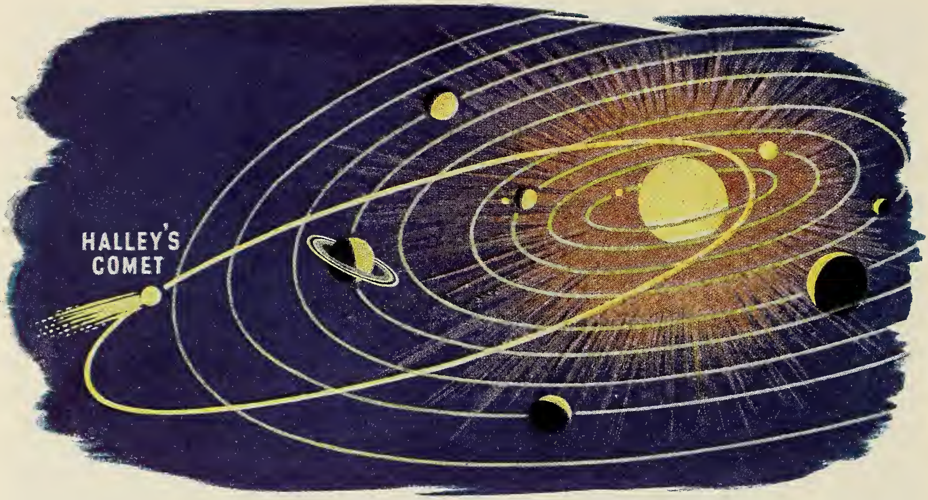
A comet is quite different from a planet. You know that a planet is a big, round ball. But a comet always has a head, and it usually has a tail. The head may be 50,000 miles across, and the tail is sometimes 100 million miles long. Not all comets have such long tails. Some comets do not even have tails.

Comets are made of gases and little bits of solids. These are bunched together in the head, but in the tail they are very far apart. You can understand this better when you learn something about the great comet called Halley's Comet. Two thousand cubic miles of its tail would not contain as much material as there is in a cubic inch of air on the earth! That is why you should not be afraid if the earth passes through the tail of a comet. In fact, this has happened several times. In May 1910, the earth passed through the tail of Halley's Comet.

A comet travels around the sun, but its orbit is very different from the orbit of a planet. You know that a planet travels in a path that is nearly a circle with the sun in the middle of it. The orbit of a comet is a long, long oval with the sun near one end of it. The tail of a comet always points away from the sun.

We can see a comet only when it comes near both the sun and the earth. Scientists can figure out the length of a comet's orbit and how fast it is traveling. So they can tell when a comet is coming close enough for us to see it. Some comets race around their orbits in only a few years. Others have such long orbits that they can





You can see why a comet can come near a planet. The orbit of a comet crosses the orbits of the planets.

be seen only once in hundreds of years. We can see comets because, like planets, they reflect light from the sun. A large comet is a beautiful sight.

Halley's Comet is the most famous one of all. It was named for Edmund Halley, a British scientist. He was the first one to figure out the path that a comet follows. Halley wrote, "Now many things lead me to believe that the comet of the year 1531 is the same as that seen in 1607 and the one I saw return in 1682. I may, therefore, with confidence predict its return in the year 1758."

On Christmas night, 1758, the comet came just as Halley had said that it would. Halley's Comet can be seen from the earth once every seventy-six years. It was last seen in 1910. No doubt, many in your class will see this comet when it comes again in 1986.

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1. *How are comets different from planets? How are they alike?*
2. *Why can a comet be seen only now and then?*
3. *Are comets part of the solar system? Explain your answer.*
4. *Which way does the tail of a comet point?*
5. *Do you think Edmund Halley was a good scientist? Give your reasons.*

What causes an eclipse?

Do you remember the story about Columbus and the Indians? When you read the story, did you wonder how Columbus knew that an eclipse of the moon would take place on a certain day? Let us see what causes an eclipse.

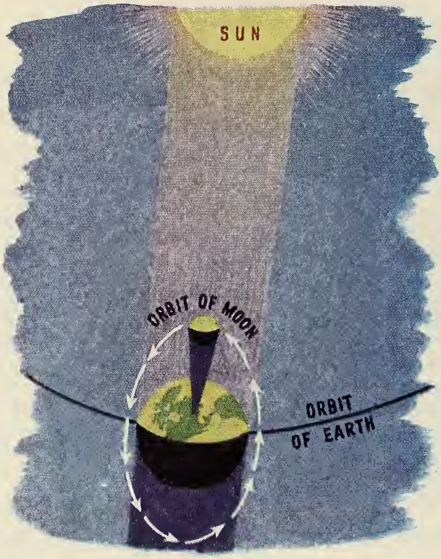
As the earth revolves around the sun, the moon moves about the earth. The earth rotates on its axis 365¼ times each year as it makes its journey around the sun. And while the earth is making this journey, the moon moves about the earth every 29½ days. The moon always keeps the same half of its surface toward the earth.

Once a month, as the moon moves about the earth, it comes in between the sun and the earth. But most of the time, it is not in a direct line between them. Every so often, though, the moon passes directly between the sun and the earth. When this happens, the moon hides the sun from the earth. Then we have an eclipse of the sun.

The moon is so much smaller than the sun that you may be wondering how the moon can hide the sun from the earth. This experiment will help you discover the reason. Take a penny in one hand and a half dollar in the other hand. Close one eye and hold the coins in front of your other eye. Have the penny near you and the half dollar farther away. Then move the half dollar still farther away until the penny hides it.

Is the penny as big around as the half dollar? Which is nearer to your eye? This experiment shows that the nearer things are, the larger they look. That is why the moon and the sun seem to be about the same size in the sky. The sun is about 93 million miles away from the earth, but the moon is only 240,000 miles away. Now do you see why the small moon can hide the big sun?

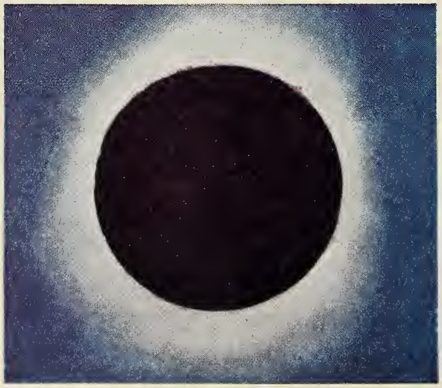
When there is an eclipse of the sun, the moon is between the earth and the sun. So the moon keeps the sun's light from getting to the earth. It makes a shadow on the earth. As the moon slowly hides more and more of the sun from the earth, the earth gets darker and darker. When the moon passes directly in front of the sun, it causes a *total eclipse.*



When the moon completely hides the sun, you can see a great mist of silvery-white light around the sun. This silvery-white light is always around the sun, but we can see it only during a total eclipse. Even if the total eclipse takes place at noon, the earth is in darkness. The stars can be seen just as we see them at night. When the moon covers only part of the sun, it causes a *partial eclipse.*

Are you wondering why there is not an eclipse every time the moon passes between the sun and the earth? You can find out if you do this experiment. Hold the penny and the half dollar just as you did before. Then move the penny until it is a little above or below a straight line from your eye to the half dollar. Then the penny does not hide any of the half dollar. So if the moon is not directly between the sun and the earth, there is no eclipse of the sun.

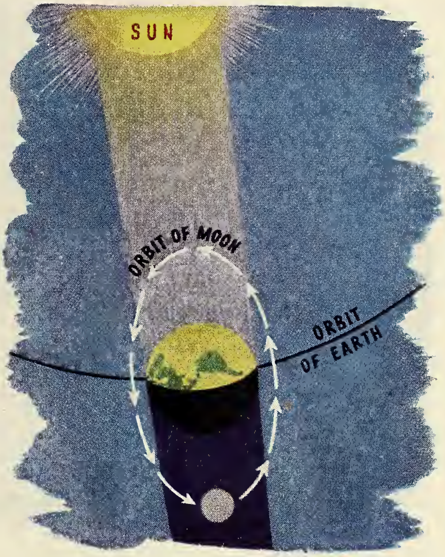
During the few minutes that an eclipse lasts, scientists can learn many things about the sun. They often go to faraway places on the earth where they can see an eclipse best. They spend many months getting ready for these few minutes when the sun is hidden. One way that scientists study an eclipse is to take pictures of it.

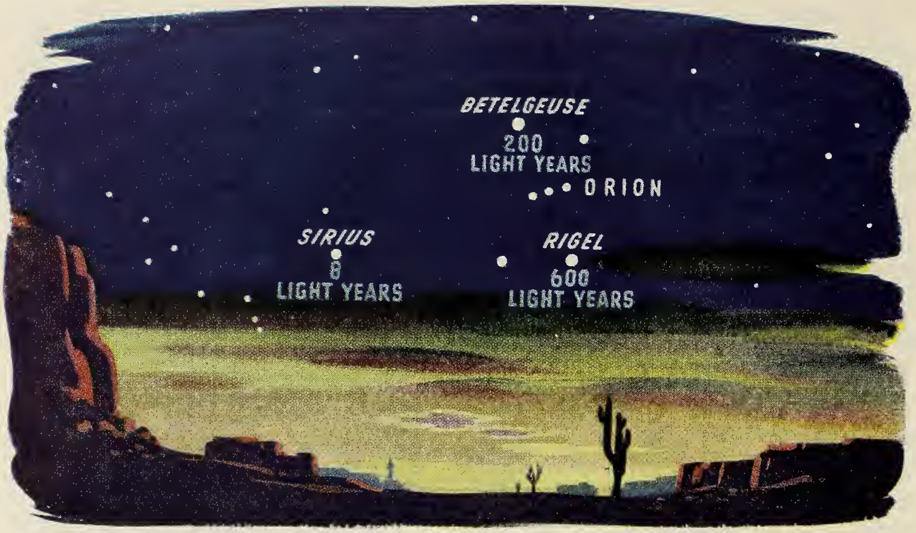


Sometime, you may want to watch an eclipse of the sun. To do this, you can look through a piece of smoked glass or some used camera films. You know that you should never look directly at the sun, not even for one second. If you do, you may injure your eyes very badly. As you watch the eclipse, you can make some drawings that show just how the moon is moving across the sun.

Scientists can tell exactly when there is going to be an eclipse. They can do this because they know exactly what paths the earth and the moon travel. They also know how fast the earth and the moon move. Scientists knew that there would be a total eclipse of the sun on July 9, 1945. It was seen in Idaho, Montana, and central Canada. On June 30, 1954, another eclipse will be seen in Minnesota, Wisconsin, and eastern Canada.

You already know that the moon can be hidden just as the sun is. Let us see how this happens. As the moon travels about the earth, sometimes the earth gets directly between the sun and the moon. Of course, light from the sun cannot shine through the earth. So the earth makes a shadow on the moon. When this happens, there is an eclipse of the moon.





The shadow of the earth on the moon tells scientists something interesting about the shape of the earth. Look at the picture of the eclipse of the moon. Is the edge of the shadow straight or curved? What does this show about the shape of the earth? Why?

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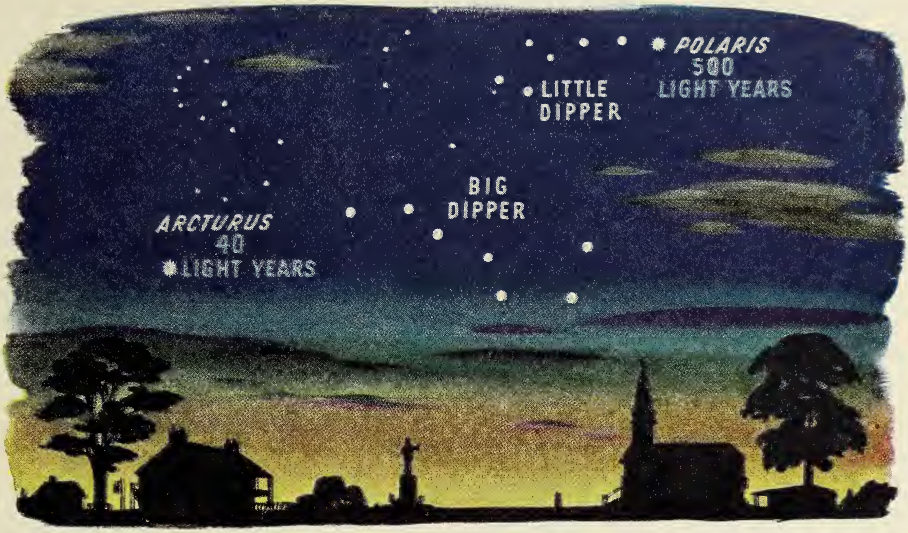
1. *What happens when there is a total eclipse of the sun?*
2. *Why do the small moon and the big sun seem to be about the same size when you see them in the sky?*
3. *What part of the sun can be seen only during a total eclipse of the sun?*
4. *During an eclipse of the moon, what shadow hides the moon? What does this shadow tell you about the shape of the earth?*

What is beyond the solar system?

THE SOLAR SYSTEM is so huge that you cannot even imagine how big it is. The planets are so far from the sun that we give their distances in millions of miles. Can you imagine how far 1,000,000 miles is? The distance around the earth is only 25,000 miles. How many times would you have to go around the earth to travel one million miles? Forty times! Then



think that the sun is 93 million miles away! And Pluto, the farthest planet, is more than 3½ billion miles from the sun!

The stars are far, far beyond the solar system. The very nearest star is almost 30,000 billion miles from the earth. The stars are so far away that scientists do not use miles to tell their distances. A mile is much too short. Using miles would be like giving the distance from New York to San Francisco in inches. So scientists use what is called a *light-year.*

As you already know, light travels 186,000 miles a second. A light-year is the distance that light travels in one year. One light-year is nearly six trillion miles. To write this number, put twelve zeros after a six like this: 6,000,000,000,000. This is a very big number. Scientists use it as the measuring stick when they talk about distances in the universe.

Now let us find out how far away some of the stars are. Sirius is the brightest star in the sky. It is near the constellation Orion in the southern sky. Sirius is a little more than eight light-years away from the earth. That is over 48 trillion miles! Just think! It takes the light from Sirius more than eight years to reach us on earth. And Sirius is one of the nearest stars beyond our star, the sun.

Do you know where Arcturus is? Find the Big Dipper. Then move your eyes along the curved handle of the Big Dipper to twice its length. There you can see the bright star Arcturus. It is forty light-years away. It is one of the nearer stars, too.

In the Little Dipper, 500 light-years away is the North Star, or Polaris. Betelgeuse, the giant red star in the constellation Orion, is 200 light-years away. Rigel, the bright, bluish-white star in Orion, is about 600 light-years from the earth. And the distances of many other stars are thousands of light-years. When you think that light takes a little over eight minutes to travel from the star that we call the sun to the earth, you can begin to realize how far away the other stars are.

The stars in a constellation seem to be close together, but they may be many light-years apart. And there are many stars too far away to be seen with the naked eye. When a scientist takes a picture of just a small part of the universe, it shows millions of stars. But scientists know that there are many more stars in the universe than even a picture shows. Scientists know that there are billions of stars in the universe.

Some of these stars are many, many times as big as our sun. Betelgeuse, one of the biggest, is a giant among stars. It would make 30 million suns the size of our sun. Some stars may have planets that revolve around them just as our sun has. Scientists do not know whether there are other solar systems, but it seems likely that there are. Perhaps someday the scientists will be able to tell us.

From what you have learned, you can see that the earth is only a tiny speck in a huge universe. The earth seems big to us. But in a universe where distances are measured in trillions of miles, the earth is just a dwarf among giants. It is only one of the billions of things in the sky. And we live on this tiny earth.

When you look up into the sky at night, you can see a bright pathway of lights going from north to south across the sky. This is the Milky Way. Powerful telescopes show that there are millions and millions of stars in it. Scientists believe that these stars form a huge group much bigger than the groups of stars we call constellations. A huge group of stars like this is called a *galaxy*. The Milky Way is our galaxy.

There may be 100 billion stars in the galaxy to which the solar system belongs. Far out beyond this galaxy, scientists have seen millions of other galaxies. Each one is probably made up of billions of stars. The universe is so vast we cannot really understand how big it is.

1. *What is a* light-year? *Why do scientists use it?*
2. *How far from the earth are the nearest stars?*
3. *When you look at the North Star, you see light. How long has it taken for the light to get from the North Star to your eyes?*
4. *What is beyond the solar system?*

QUESTIONS TO ANSWER

1. Describe the things that are in the universe. Be sure to tell about each thing you have studied.

2. Which of these are in the solar system? Earth, Polaris, Sun, Rigel, a comet, Pluto, Sirius, Saturn, Moon.

3. Explain why you are not afraid that another planet or a comet will hit the earth.

4. Why do you think that scientists want more powerful telescopes than they now have?

5. Which of these sentences about planets are true?

a) They revolve around the sun in certain orbits.
b) They are larger than the nearest stars.
c) They all travel in the same direction around the sun.
d) They can be seen because they reflect light from the sun.
e) They are all the same size and the same distance from the sun.
f) They get their light and heat from the sun.
g) They rotate on an axis.

6. Put these in order according to their distance from the earth. Look at your book while you are doing this. Begin with the nearest one. Sun, Venus, Moon, Sirius, Betelgeuse, Arcturus, Rigel.

7. Suppose that you wanted to make a model of the solar system. If you used one inch for one million miles, how far away from the sun would you put each of the planets? Could you build this model in your schoolroom or on the playground? Why?

THINGS TO DO

1. Find out when there will be an eclipse of the moon. Watch the eclipse. If you can, make drawings of the earth's shadow as it passes across the moon.

2. In 1946, Mars was only 60 million miles from the earth. Sometimes it is 248 million miles away. Find out why its distance from the earth changes. Then make a drawing to show where Mars and the earth are in their orbits when they are close together and when they are far apart.

3. Find out what a planetarium is and what cities in our country have planetariums. If you live near one of these cities, try to visit the planetarium.

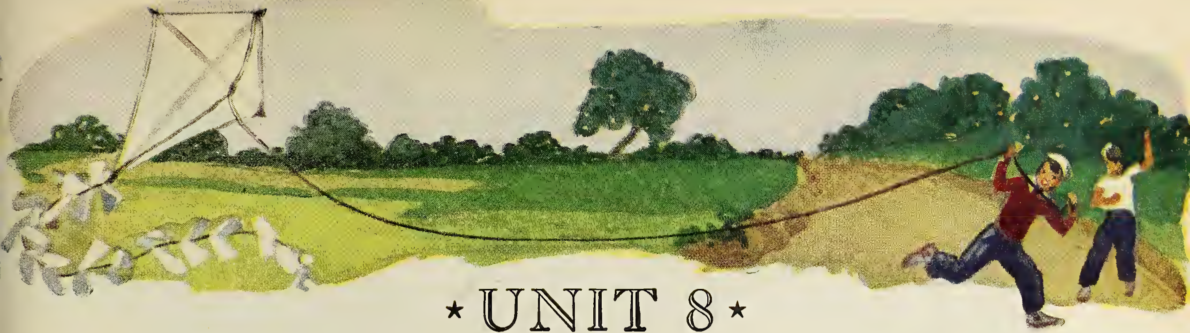
4. Read in newspapers or magazines to find out when one of the planets can be seen. Then try to see this planet in the sky. Look at it every few weeks. Each time, make a drawing to show where the planet is. Also show the stars near it. Be sure to put the date on each drawing. What do your drawings show?

5. Learn where some of the largest telescopes are. If you live near any of these places or take a trip to it, try to see the telescope.

6. Find out when there will be an eclipse of the sun near your home. How can you watch this?

★ *In Unit Eight You Will Learn* ★

- ★ *What the different kinds of airplanes are* ★
- ★ *How an airplane is held up in the air* ★
- ★ *How an airplane is controlled* ★
- ★ *What kinds of engines drive airplanes* ★
- ★ *What an airplane trip is like* ★



★ UNIT 8 ★

How Do Airplanes Fly?

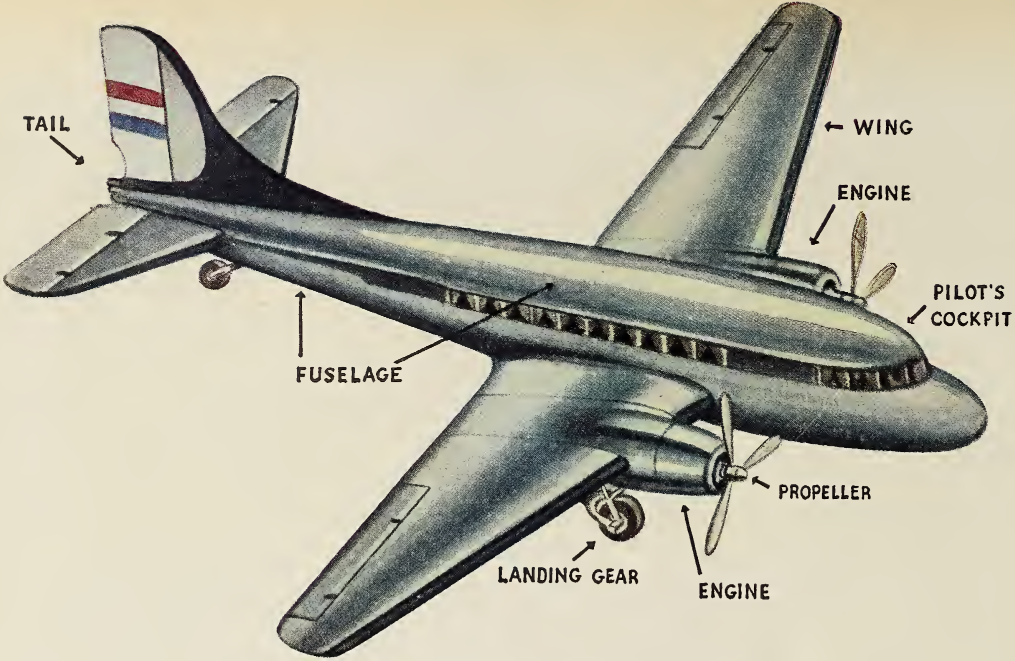
WE LIVE on the bottom of an ocean—the biggest and deepest ocean in the whole world! It covers the entire earth, both land and water. And it is at least 500 miles deep. You know what this ocean is. It is an ocean of air.

Machines that move through this air ocean are called airplanes. They can cross mountains, deserts, forests, jungles, rivers, lakes, and seas. And they can do this without using roads, tunnels, bridges, or canals. All they need is enough room on the earth's surface to go up into the air and then come down again. While they are up in the air, they are as free as the wind or the birds.

Airplanes can move even faster than the wind or the birds. In a little more than six hours, an airplane can fly from Los Angeles, California, to Washington, D. C. This is a distance of nearly 2300 miles. So the speed of the airplane is over 360 miles an hour. That is more than six miles a minute! The distance from New York City to London, England, is almost 3500 miles. An air trip from one city to the other takes about twelve hours. By air, we can now travel to any place on earth in less than sixty hours!

Of course, you know that airplanes carry passengers, mail, express, and freight. But that is not all they do. In a few hours by air, explorers can travel to out-of-the-way places that would take days or even weeks to reach by land or water. Insect pests on growing plants are killed by spraying or dusting poison on the fields from airplanes. Not long ago, airplanes saved a beautiful forest in Oregon. They sprayed DDT on the trees and killed millions of insects.

Forest rangers use airplanes to find small forest fires. Men jump from the planes with parachutes and put out the fires before great damage is done. Patrol planes of the Coast Guard find ships that are in trouble and send boats to rescue them. A few years ago, a map of our country was needed in a hurry. Airplanes took thousands of photographs. Then the photographs were put together to make the map.



Most airplanes have the parts shown in this picture.

The whole job was done in much less time than it could have been done in any other way. And the map was much more accurate!

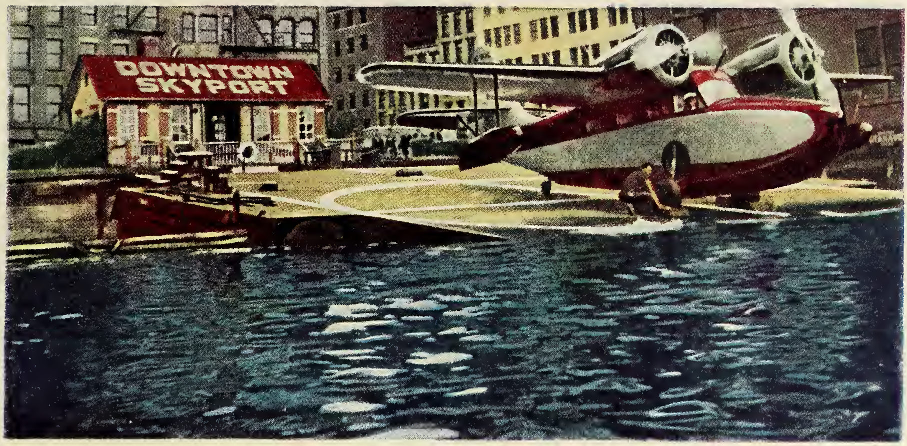
In this unit, you will learn about the different kinds of airplanes. You will also find out how they move through the sky.

What are the different kinds of airplanes?

Long before the first airplane was made, people used balloons to go up into the air. But balloons are not used very much today except by scientists who are studying the air high above the earth. A balloon has a cloth or rubber bag filled with a gas that is lighter than air. This light gas makes it possible for the balloon to float in the air.

An airplane is built of light but strong materials, such as aluminum, magnesium, wood, or even cloth. Its parts are usually hollowed out to make them lighter. In spite of all this, an airplane always weighs more than air. If it did not have a special way of staying up in the air, it would drop to the earth like a stone. Sometimes this does happen when something goes wrong in an airplane. Then there may be a serious accident.

Most airplanes are driven through the air by an engine that turns a propeller. Large airplanes have two or more engines and propellers. But the first thing that you probably notice about an airplane is its wings. They



This is a small amphibian plane. It has wheels that can be pulled up when the plane is going to land on water.

stick out on either side of its long, narrow body. The body of an airplane is called the *fuselage*. Most of the airplanes built today are *monoplanes*. They have one pair of wings. Mono- means one. Airplanes with two pairs of wings are called *biplanes*. Bi- means two. Biplanes are seldom used now. Years ago, even *triplanes* with three pairs of wings were built.

The wings of an airplane are usually attached to the top, bottom, or sides of the fuselage near the front, or nose. If a plane has only one engine and propeller, they are usually put in the nose of the fuselage. But if a plane has two or more engines and propellers, they are usually fastened to the wings. At the rear of the fuselage is the tail.

Under the fuselage and the wings is the *landing gear*. There are several kinds of landing gear. Some kinds are built to use on the ground. Others are made to use on the water. Airplanes that take off and land on the ground are called *land planes*. Their landing gear usually has wheels. Sometimes skis or runners are used in place of wheels if the airplane must take off and land on snow or ice.

Airplanes that take off and come down on water are called *seaplanes*. Some seaplanes look like land planes except that they do not have wheels. Instead, they have floats that are called *pontoons*. Other seaplanes have a fuselage shaped like a boat. So this kind is often called a flying boat. Another kind of airplane can take off and come down on either land or water. This kind of plane is called an *amphibian* plane. It has floats and wheels that can be pulled up.

This picture shows how three gliders can be towed behind an airplane.

A *glider* looks very much like a land plane. But it has no engine or propeller. The landing gear may be one or more wheels or small pontoons for landing on water. Some way must be provided to get a glider up into the air. It is usually pulled up into the air with a rope fastened to an automobile or an airplane. After the glider is in the air, the rope is unfastened. A glider can stay up for a long time and travel many miles. To do this, the pilot must know how to use the currents of warm air that are pushed up from the earth. As many as three gliders at one time have been towed in a "sky train" behind an airplane.

The most unusual kind of airplane is called a *helicopter*. It has no wings like those of an ordinary airplane. Instead, it has a set of rotating blades on top of the fuselage. They are turned by an engine. There is no propeller on the nose, but a small propeller on the tail helps in steering. A helicopter can take off by going straight up and land by coming straight down. So it can land in a very small place. It can fly forward, backward, and sideways. It can even stand still in the air!

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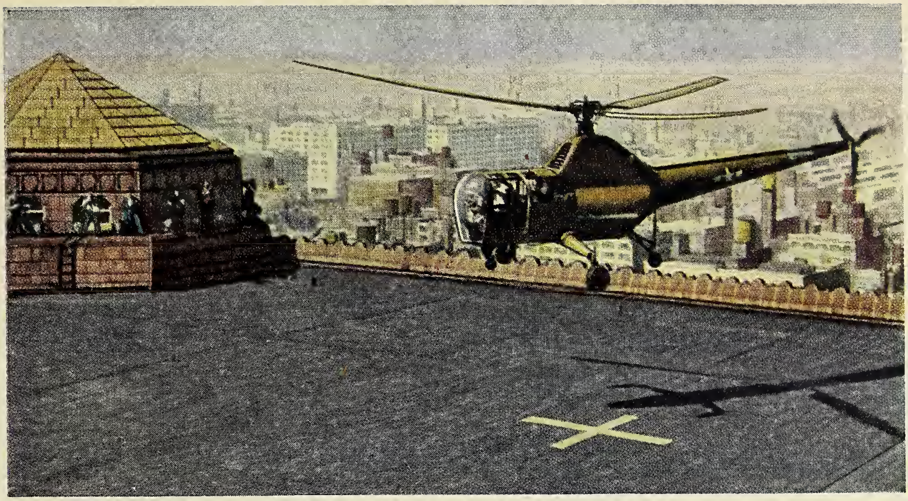
1. *Why do airplanes have different kinds of landing gear?*
2. *What do we call the body of an airplane? The front of an airplane? The rear of an airplane?*
3. *What does* monoplane *mean? What does* biplane *mean? Which is commoner today?*
4. *How is a helicopter different from an ordinary airplane?*



A helicopter can bring the mail directly to the post office in a big city, because it can land on the roof.

How is an airplane kept up in the air?

For hundreds of years, people watched flying birds and insects, and they saw seeds that glided through the air. How wonderful it would be to fly, they thought. One old story tells about a man named Daedalus. He made wings of feathers and wax for himself and his son Icarus. Off they soared through the air, flapping their wings. But Icarus flew too near the sun. The wax in his wings melted, and he fell into the sea. Of course, we do not believe this old story. Yet it does show that people of long ago wanted to fly.

As the years went by, inventors thought up all sorts of queer contraptions for flying. One invention was a pair of wings that flapped like the wings of a bird. Another invention was supposed to be rowed through the air with oars. Needless to say, few of these flying machines ever got off the ground. Those that did soon crashed. Usually the pilot was injured or even killed.

Then one day about forty-five years ago, two brothers, Orville and Wilbur Wright, tried out a flying machine that they had made. The Wright brothers had already built a glider that stayed up in the air for some time. But now they had added something new. Their flying machine had two propellers driven by a small gasoline engine. They locked up their bicycle shop in Dayton, Ohio, and went off to Kitty Hawk, North Carolina. Here they found a sandy beach with enough wind for the test. On the beach, they built a runway sixty feet long to help their biplane get into the air.

At last, everything was ready. Orville Wright sat at the controls. The engine was started, and the propellers began to spin around. The flying machine moved down the runway, slowly at first, then faster and faster. It rose into the air! Twelve seconds later, it crashed into a sandbank 120 feet from the end of the runway. The damage was soon repaired, and the plane made three more flights that day. The fourth and last flight was the longest. The biplane stayed up in the air for 59 seconds and traveled 850 feet. Of course, that is not much compared with what modern planes can do. But the first real airplane had flown under its own power.

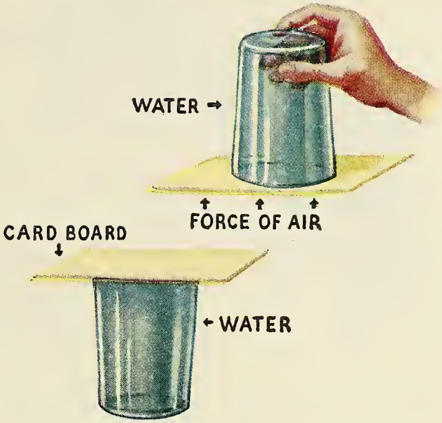
Why did the Wright brothers succeed after so many others had failed? For one thing, their airplane was as light as they could make it. Then, too, the gasoline engine supplied enough power without being very heavy. But even more important, they had invented a better set of controls than any that had ever been made before. In fact, the controls of the most modern airplanes were developed from those that the Wright brothers first used. Later in this unit, you will learn how the controls of an airplane work.

Now let us find out what keeps an airplane up in the air. As you know, the force of gravity pulls down on everything in the world. When you lift something, you must use enough upward force to overcome the downward pull of gravity on the thing you are lifting. To get an airplane off the ground and keep it in the air, enough force must push upward to overcome the downward pull of gravity.

What supplies this upward push to an airplane? Strangely enough, it is the air. You know that air is a material. It takes up space, and it has weight. Gravity pulls down on the air just as it pulls down on everything else. Air pushes against the earth and everything on the earth. It pushes against your body, too. If air can push, it must have force. When the air is still, you do not notice its force. But when the air is moving, you can feel its force. You know that wind, or moving air, can make things move.

Air pushes in all directions—downward, upward, and even sideways. If you blow into a toy balloon or pump up a basketball, air pushes against the top, the bottom, and the sides. The whole balloon or ball swells out as the air pushes against it. You can do an experiment to show that air pushes upward as well as downward.

Put a glass tube into some water. Hold your finger tightly over the top of the tube and lift the tube out of the water. Why does water stay in the tube? Take your finger away from the top of the tube. What happens to the water now? When your finger closed the top of the tube, air pushed up on the water and kept it in the tube. But



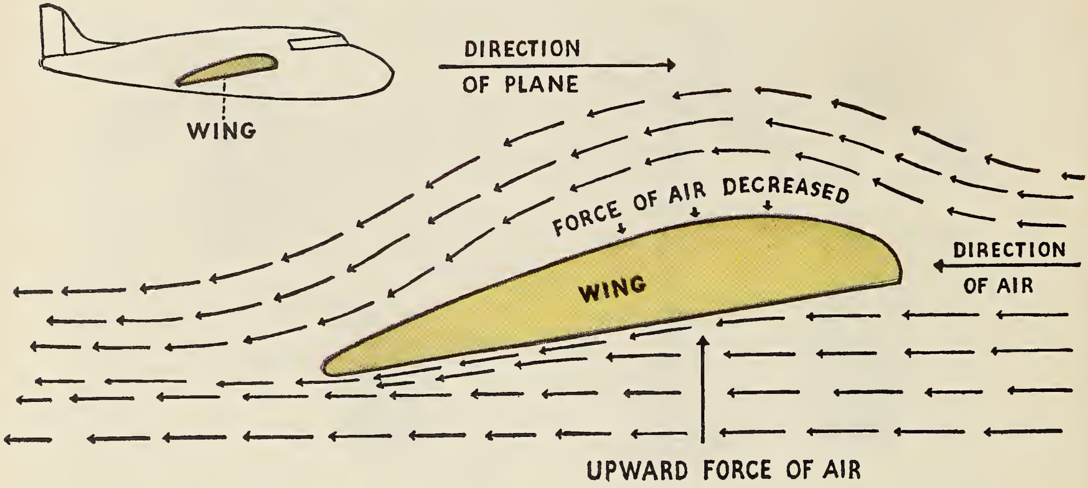
when you took your finger away, air also pushed down on the water inside the tube as well as up on it. Then the water ran out of the tube.

Here is another experiment to show you that air pushes upward. Fill a glass full of water. Be sure that the water comes right up to the top. Now put a piece of smooth cardboard over the glass. Hold the cardboard tightly on the glass and carefully turn the glass upside down. Then take your hand away from the cardboard. Why does the water not run out? What keeps the cardboard from falling? Gravity pulls down on the cardboard and on the water. But the air pushes up against the cardboard with even more force. It holds the cardboard tightly against the glass. So the water cannot run out.

These experiments show that air can push upward with enough force to overcome the downward pull of gravity. To lift an airplane off the ground and keep it up, air must be made to push up harder on the plane than gravity pulls down. An airplane is built to make the force of air do this. You can probably guess that the wings and the propeller have something to do with producing the upward force. Let us see how they help lift the plane off the ground.

Did you ever try to fly a kite when there was not much wind? You had to run with the kite to get it up. As you pulled on the string, the kite slanted. Air rushed against the underside, and the force of air lifted the kite into the air.

Now look at the picture on the next page. It shows how the wing of an airplane is attached to the fuselage. Do you see that the wing slants a little? When the airplane is moving,



air rushes against the underside of the wing. The force of the air pushes the wing up. Of course, this force helps lift the plane. But even more force is produced in a different way.

Look at the picture again. Do you see that the top of the wing is curved? You can also see that the wing is thicker in front than it is behind. This shape of the wing makes the air push up with more force. You can do some experiments to see why this is true.

Cut a strip of paper about an inch wide and ten inches long. Fold one end over your thumb and hold it under your lips, as shown in the picture. Now blow over the top of the strip. What happens? When you are not blowing, the strip hangs down. But when you blow, the strip comes up and stands straight out. What lifted the paper? The force of air up against the strip must be greater than the force of air down on top of the strip. So the strip is forced upward. This must mean that when air is moving fast, its force down on the strip is less than the force of the air pushing up.

Another experiment will help you see that this is true. Cut two paper strips about an inch wide and ten inches long. Hold the strips about an inch apart, as shown in the picture. The strips will hang straight down. Now blow down between the strips. This will make the air between them move very fast. What happens?

Before you blow between the strips, the force of air is the same on both sides. So the strips hang straight down. But when you blow between the strips, the air moves faster. So the force of air between the strips becomes less than the force of air on the outside. The greater force on the outside pushes the strips together.

Now you can understand what happens when air rushes over the top of an airplane wing. The air that goes over the curved top has to travel farther than the air that goes under the bottom of the wing. You can see that this is true by looking at the picture. The bottom of the wing is straight. The air that goes over the top of the wing moves faster, because it has to travel farther.

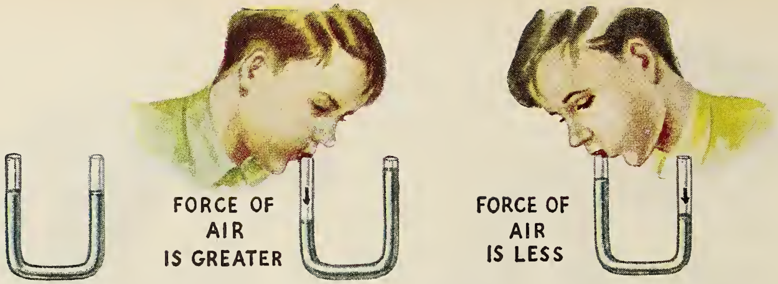
The experiments with the paper show what happens when air moves faster on one side of something than on the other side. The force of air is less on the side where the air moves faster. This means that the force of air down on top of the wings is less than the upward force on the underside. This upward force is called the *lift*.

An airplane stays up in the air when the upward force of air on the wings is greater than the downward pull of gravity. Or as scientists say, the lift is greater than the weight of the plane. This lift is caused in two ways.

1. Air rushes against the slanting underside of the wings and pushes them up.
2. Air moves faster over the curved top of the wings than it does over the straight bottom. So the force of air is less on top of the wings than it is up against the bottom.

Curiously enough, air rushing over the wings produces about three times as much lift as air rushing against the underside. You can get an idea of what happens by doing this experiment. Fill a U-shaped glass tube half full of water. The level of the water in both sides of the tube will be the same.

Now blow very gently into one end of the tube. The water will go down on this side of the tube and up on the other side. Blowing makes the force of air greater on one side than on the other. Then suck very gently on the other end of the tube. Again


FORCE OF AIR IS GREATER
FORCE OF AIR IS LESS

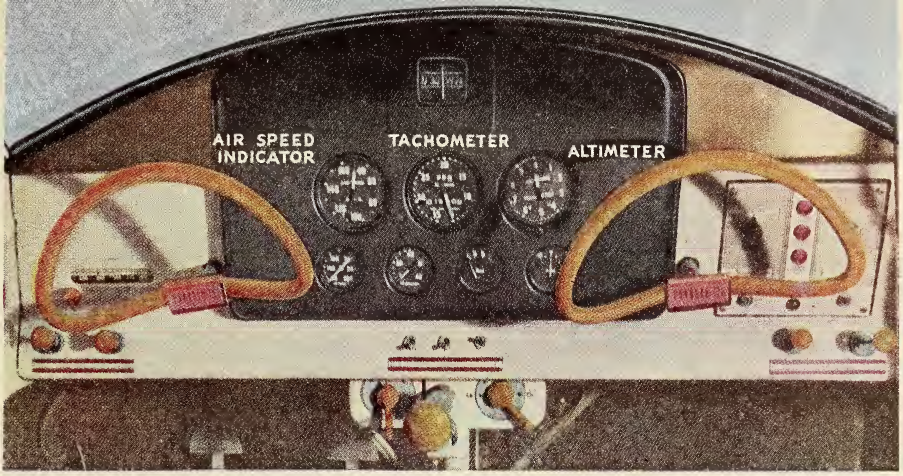
the water comes up on this side and goes down on the other. But it does this for a different reason. Sucking makes the force of air less on one side. Air pushes down harder on the other side, and the water goes up.

You can easily imagine what would happen if you blew on one end of the tube while someone else sucked on the other end. Water would shoot up on the side where the force of air was less. The difference in the force of air between the two sides would be much greater. In an airplane, the difference in the force of air on both sides of the wing is great enough to overcome the pull of gravity and to lift the plane.

A propeller turned by an engine drives an airplane fast enough to keep it up in the air. As the propeller spins around, it pushes back on the air and drives the plane forward. If this seems queer, stop and think a minute. To make a coaster wagon or a scooter go forward, you push back on the ground with your foot. A rowboat or a canoe goes ahead when you push back on the water with oars or a paddle. And a ship moves forward when its propeller pushes back against the water.

An airplane propeller may have two, three, four, or even more blades. In a modern airplane, the slant at which the blades cut into the air can be changed. As the plane goes higher and the air gets thinner, the slant of the blades is made greater to take a bigger "bite" of air. This keeps the propeller from spinning too fast and wasting the force of the engine.

1. *Why do you think that people have always wanted to fly?*
2. *Give some reasons why the Wright brothers' airplane was the first to make a successful flight.*
3. *Explain as carefully as you can what keeps an airplane up in the air. Draw some simple pictures on the blackboard to show what you mean.*
4. *What does a propeller do to help keep an airplane up in the air?*
5. *In what two ways is the lift produced in an airplane? Which way gives most of the lift?*



This is the instrument board of a small airplane. A large plane has many more instruments on its board.

How is an airplane controlled?

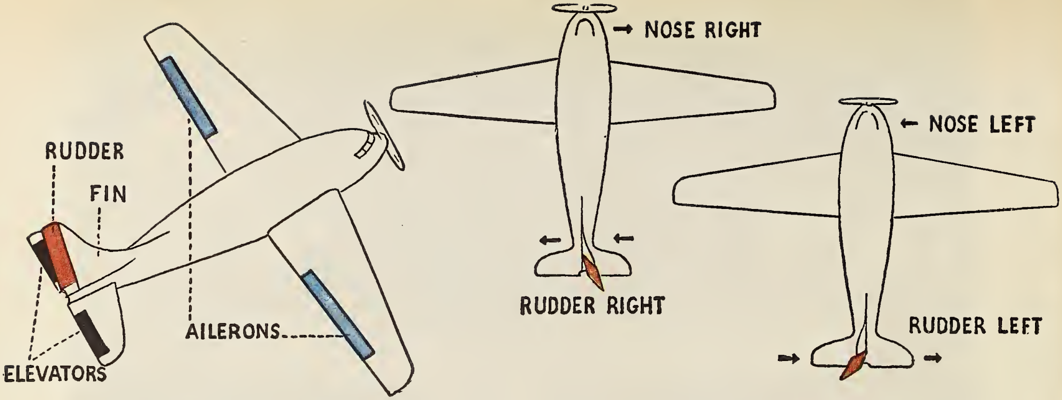
You cannot learn to fly an airplane just by reading a book. But you can find out some of the things a pilot must do to guide a plane through the air. Before any person is allowed to fly a plane all by himself, he must spend many hours practicing with a teacher. To steer a wagon, a scooter, or even an automobile, all you have to do is turn right or left or keep going straight ahead. The wheels run along the ground, and they go up or down over hills and bumps.

In an airplane, the pilot must make three different kinds of turns.

1. He can turn the plane to the right or left.
2. He can point the nose up or down.
3. He can tilt the plane sideways to the right or left.

Often, the plane must make two kinds of turns, or even all three, at the same time. You can see why it takes more skill and more controls to steer an airplane than it does to steer an automobile.

Now let us look inside an airplane and see what some of these controls are. In front of the pilot's seat are several instruments for him to watch. One of these is the *tachometer*. This shows how fast the engine is going. The *air-speed indicator* gives the speed of the plane through the air. How high the plane is above the earth is shown by the *altimeter*. A magnetic compass tells the pilot in which direction the plane is heading. The *fuel gauge* shows how much gasoline there is in the tanks. Other gauges give the temperature and the pressure of the oil in the engine. Some planes



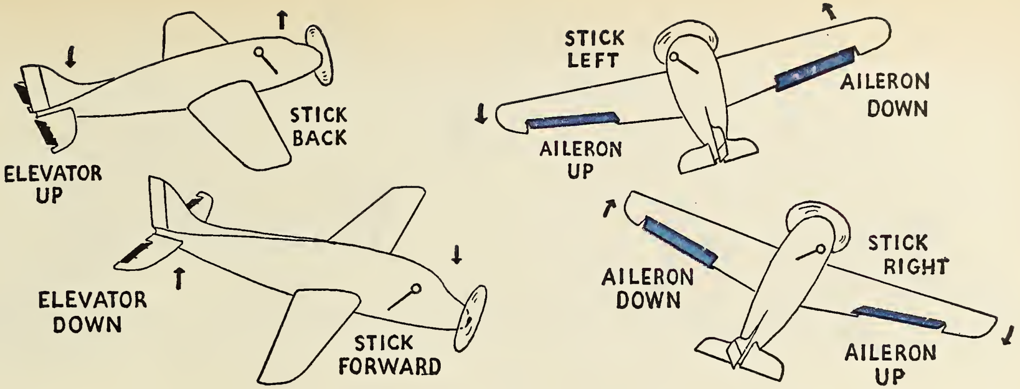
have many more instruments to watch.

Near the floor in front of the pilot's seat are two pedals. These can be worked by his feet. They are connected to the *rudder*. This is the upright part of the tail that can be moved from side to side. Pushing on the right pedal turns the rudder to the right. Then air hits the right side of the rudder and pushes the tail to the left. This makes the nose of the plane point toward the right. Pushing on the left pedal does just the opposite. It makes the nose point to the left. Just ahead of the rudder is a part of the tail called the *fin*. It does not move, but helps keep the plane straight when the rudder is not turned.

Directly in front of the pilot is a lever called the *stick*. This lever can be moved backward and forward or from side to side with the hands. In some planes, a wheel that moves back and forth is used instead of a lever. The stick is connected to the *elevator*. This is the flat part of the tail that can be moved up and down. Pulling back on the stick raises the elevator. Air hits the upper side of the elevator and pushes the tail down. This makes the nose of the plane point up. Pushing the stick forward lifts the tail and makes the nose point down. Just ahead of the elevator is a part of the tail called the *stabilizer*. It does not move, but it helps keep the plane level when the elevator is not being used.

There are movable flaps on the rear edge of each wing. These flaps are called *ailerons*. They are connected to the stick. Moving the stick to the right raises the right aileron and lowers the left aileron. Air rushing over the right wing hits the raised aileron and pushes this wing down. And air rushing under the left wing hits the lowered aileron and pushes that wing up. So the plane tilts sideways to the right. Moving the stick to the left does just the opposite. It makes the plane tilt to the left.

If you have a small model airplane or a toy glider, you can see how an airplane is controlled. First, try moving the rudder from side to side. Then move the elevator up and down. Raise one aileron and lower the other. Also



try this. Turn the rudder to the right, raise the elevator, and put the right aileron up and the left one down. Set the controls in other ways, too.

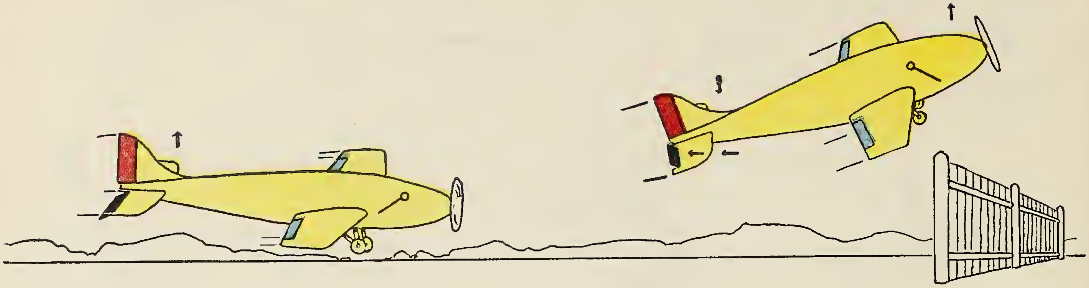
Perhaps you are thinking that it is not so hard to fly an airplane. All you have to do is push pedals, move a stick, and watch some instruments. But it is not really so easy as that. It takes a pilot a long time to learn how to move the controls so that they work together. Suppose that we pretend to take a short flight just to see what a pilot might have to do.

The plane is rolled out, and the pilot climbs into his seat. He looks at the fuel gauge to see whether there is enough gasoline in the tanks. Then he waves to a mechanic to start the engine. This is done by spinning the propeller or using an automatic starter. When the engine is going, the pilot lets it run for a while to warm up. He looks at the oil gauges to see whether the temperature and the pressure are right. At last, everything is ready.

The blocks in front of the wheels are pulled out, and the propeller drives the plane down the runway. Moving a plane along the ground in this way is called *taxiing*. At the end of the runway, the pilot turns the rudder and heads the plane into the wind. If possible, a plane always takes off into the wind, because the wind rushing past the wings gives an extra lift to the plane.

The pilot opens the *throttle*. This is a lever that controls the flow of gasoline to the engine. The propeller turns at full speed when the throttle is open. As the propeller drives the plane swiftly down the runway, the pilot pushes the stick forward. This lowers the elevator and lifts the tail off the ground. Now the plane is going even faster. The pilot looks at the air-speed indicator. The plane is moving fast enough to take off. He pulls slowly back on the stick. This raises the elevator and pushes the tail down. The nose of the plane points up, and the plane rises into the air.

Not a moment too soon! The wheels just clear the fence at the end of the runway. The plane keeps on climbing. But there, straight ahead, is a tall



chimney. The pilot pushes on the right pedal and at the same time moves the stick back and to the right. The plane makes a sharp right turn with its wings tilted sideways to the right.

You can easily see why this happens. Pushing the right pedal turns the rudder to the right. Wind striking the rudder turns the nose of the plane to the right. When the stick is moved back, the elevator is raised and the wind pushes the nose up. The pilot must do this in making a turn to keep the plane at the same height. Moving the stick to the right raises the right aileron and lowers the left aileron. So the plane tilts to the right.

The pilot flies around for a while and then decides to land. He knows that a good landing is much harder to make than a good take-off. First, he circles around the field. He picks out a runway where the wind will blow toward the nose of the plane. If possible, a plane always lands into the wind. Then he pushes forward on the stick to point the nose slightly down as he glides toward the field.

Now the plane is near the ground. The pilot pulls back on the stick to lower the tail slightly. The plane skims along just a few feet above the ground. The pilot closes the throttle, and the plane slows down. As the plane loses speed, it also loses lift. It settles gently to the ground with both wheels and the tail touching at the same time. This is called a "three-point" landing.

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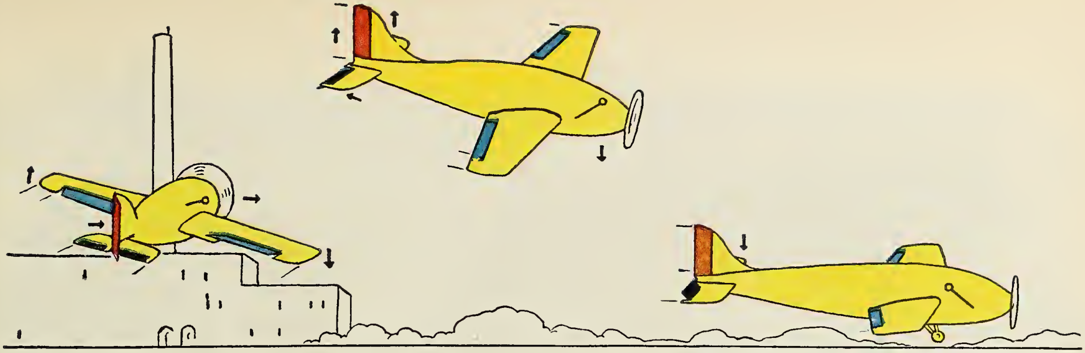
1. *Why is an airplane harder to control than an automobile?*
2. *Make a list of the things that a pilot must do to take off and land.*
3. *Why does a pilot try to have his plane take off into the wind?*
4. *What does "three-point" landing mean?*
5. *Explain what each of these is used for.*
   Tachometer Altimeter Rudder Stick Elevator Fin
   Compass Air-speed indicator Stabilizer Ailerons Throttle



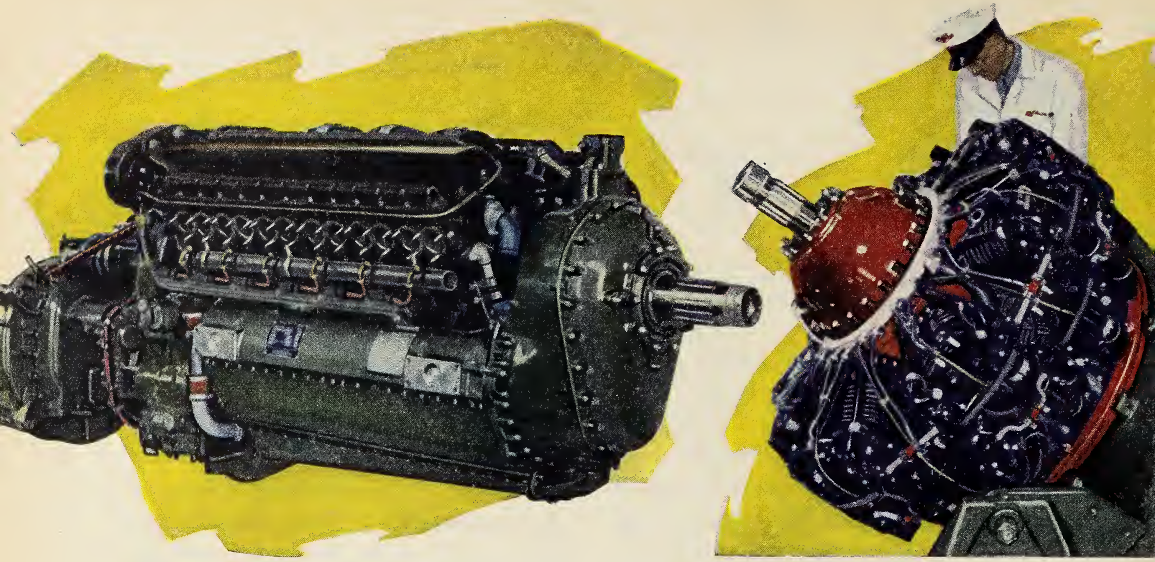
What kinds of engines drive airplanes?

An airplane must go fast enough for the upward force of air to overcome the downward pull of gravity. Otherwise the plane cannot get into the air and stay up. But to go fast enough, an airplane must have a powerful engine. Before planes could be made to fly, inventors had to build an engine that would give enough speed without being too heavy. They tried all sorts of things. One flying machine had pedals pushed by the feet. Another one had a steam engine! Of course, these things had either too little power or too much weight.

Then the gasoline engine was invented. It gave enough power, and it was not too heavy. The Wright brothers used a small gasoline engine to turn the two propellers of their airplane. They built the engine themselves. It was very much like the engines used in the automobiles of that time. As you know, all gasoline engines get their force from exploding gas. The Wright brothers' engine was fairly light, but it had enough power to drive their plane along at thirty miles an hour.

Modern airplanes are much bigger and heavier than the first airplanes. They must go at least two or three times as fast to get into the air. Much more powerful engines have been built to drive modern planes along at high speeds. Some of these engines weigh four times as much as the Wright brothers' entire airplane.

There are two kinds of gasoline engines used in the airplanes of today. One kind is called the *in-line* engine. It has its cylinders in a straight line with the shaft that turns the propeller. The cylinders are the places where the gas is exploded to make the engine turn. Large in-line engines usually have two or more rows of cylinders. If you look at them from one end, they are shaped like a V or a W. In-line engines are nearly always cooled by a liquid that flows in the hollow spaces around the cylinders. The same liquid is often used in the cooling systems of automobiles in winter. It does not boil away quickly at high tem-



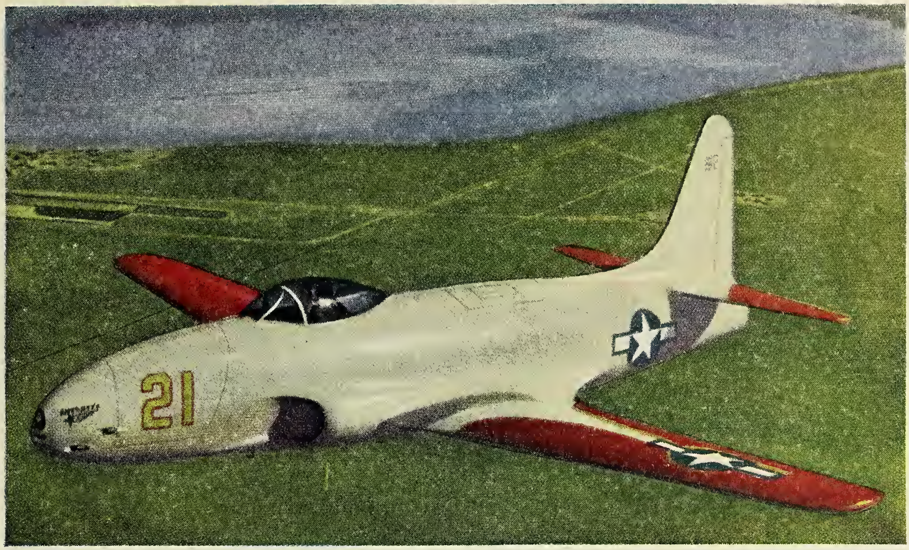
The engine on the left is an in-line engine. The one on the right is a radial engine.

peratures, and it does not freeze easily at low temperatures.

The other kind of engine has its cylinders arranged around the propeller shaft like the spokes of a wheel. It is called the *radial* engine. A large engine of this kind may have two or three circles of cylinders, one behind another. Radial engines are cooled by the air that rushes past them. To get the heat away quickly, the cylinders are made with many thin pieces of metal sticking straight out from their sides. A radial engine does not have the extra weight of the liquid needed to cool an in-line engine. But the cylinders in a radial engine stand out around the propeller shaft and slow the plane down.

High above the earth the air is thin. Both kinds of airplane engines would have trouble in getting enough oxygen to burn the gasoline completely. So a special high-speed air pump is used to get more oxygen into the cylinders. A pump like this is called a *supercharger*. It presses the thin air together and forces it into the engine. For flying very high above the earth, two superchargers are sometimes used. They force much more oxygen into the cylinders.

Not many years ago, scientists discovered a new way of driving planes through the air. This new way is called *jet propulsion*. No propeller is needed. Air rushing in through the front of the plane is mixed with kerosene. Then the mixture of kerosene and air is burned. Very hot, expanding gases rush out at the rear of the plane. This drives the plane forward.



An experiment that you can do very easily will show you how a backward rush of gas can drive something forward.

Get a toy balloon. Fill it with air by blowing into it. Hold the opening between your fingers to keep the air in. Now point the balloon away from you and let go of it. What happens? Do you see how air rushing out the back drives the balloon forward? A steady stream of gases from a jet engine drives an airplane forward in the same way. The picture on this page shows a jet-propelled plane. How is it different from most other planes?

Jet-propelled planes have traveled faster than 600 miles an hour. But they use more fuel than planes driven by gasoline engines. So they cannot stay up in the air for very long at a time or carry a big load. Probably for some time to come, in-line engines and radial engines will still be used in planes that make long flights and carry heavy loads.

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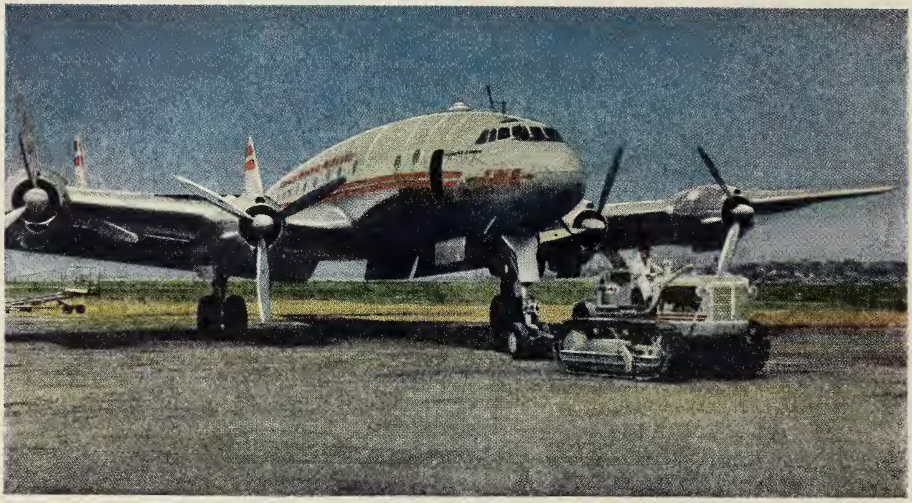
1. *Why did inventors find it hard to get an engine that would lift an airplane off the ground?*
2. *How are in-line engines different from radial engines? How are they alike?*
3. *Why do airplane engines need superchargers?*
4. *Are all airplanes driven by propellers? Explain your answer.*



The ground in an airport is often covered with a wire mesh to make a hard surface.

What is an airplane trip like?

EVERY YEAR, airplanes carry several million passengers and many tons of mail and express between cities in our own country and across the seas to other lands. More than a dozen companies, or *air lines*, provide us with air transportation. Their planes fly on regular schedules over certain routes called *airways*. Almost every city has its *airport*, where planes can land and take off. And many other *air fields* are scattered throughout our country for use in an emergency.

To find out what air travel is like, suppose that we take an imaginary airplane trip from Chicago to New York City. In most big cities, the airport is in the outskirts where there is a large, open space with no tall buildings around it. The airport is usually a mile or more square. Along the sides of the airport are some low buildings with the names of different air lines on them. These are the *hangars*, where the planes are kept. A small tractor pulls the planes in and out of the hangars. If a plane tried to taxi in or out, the blast of air from its propellers might wreck the building or damage other planes.

Another low building at the side of the airport looks somewhat like a railroad station or a bus station. This is the administration building. Inside are ticket windows, a waiting room, places to check baggage, send telegrams, or make telephone calls, a restaurant, washrooms, and a newsstand.

Before starting its trip, this plane is being air-conditioned by the red truck. The truck carries air-conditioning equipment from plane to plane in the airport.

A blackboard on one wall shows when planes are expected to arrive and leave. At a counter, a clerk looks at your ticket to make sure that it is all right. He also weighs your suitcase. Every pound over a certain amount costs extra on an airplane.

From a loud-speaker you hear, "Flight Eight, departing for New York, now loading. All aboard, please!"

You go out of the building and down a covered passage. There on the runway is a big monoplane with four engines and four propellers. Sacks of air mail are being loaded into a space under the pilot's cabin in the nose of the plane. Meanwhile, your suitcase and other pieces of baggage are being put in another space near the tail. A set of steps has been rolled up against a door in the side of the plane.

Climbing the steps, you go into the passenger cabin. There are seats on either side of an aisle. A young woman looks at your ticket and shows you where your seat is. She is the stewardess, or hostess. Her job is to take care of the passengers, serve the meals, and answer questions.

Soon people are sitting in all the seats. The pilot, or captain, and the co-pilot, or first officer, come into the passenger cabin. They go up the aisle and through a door into their cabin in the nose of the plane. Each one has a separate seat with a complete set of controls. In front of the two seats are over 200 instruments to watch. The cabin also contains a radio transmitter and several radio receivers. Need-

The pilot and the co-pilot are ready to take off.

less to say, the pilot and co-pilot have plenty to do while the plane is in the air. Before they can fly a big plane like this one, they must have at least 1200 hours of flying experience. They must also be in very good health.

Now the door of the passenger cabin is shut tight, and the steps are rolled away. The stewardess tells you and the other passengers to fasten your safety belts. They will keep you from being jolted out of your seat by a sudden bump. Safety belts are used in taking off or landing and sometimes in bad weather.

The plane is ready to leave, but many things have happened that you did not see. Mechanics checked the entire plane to make sure that everything was in good working order. Gasoline and oil were put in the plane. So was water for drinking and washing. There is a washroom in the tail of the plane. The kitchen, or *galley*, is also in the tail. It has been well stocked with food. You will eat supper in the plane.

The pilot and co-pilot have been busy making a complete flight plan. This plan shows the exact route over which the plane will travel and the time when it is expected to fly over certain points. This information is sent to airports along the way, so that people can watch for the plane.

Because bad weather is still the greatest danger in flying, the very latest weather reports have been carefully read. At Chicago, the sky is cloudless and the air is clear. The weather report says, "Sky clear, visibility fifteen miles plus." Far-

These dispatchers in the control tower of a large airport give directions to all airplanes that land or take off from the air field.

ther along toward New York City, there are a few clouds but no rain or fog. At 17,000 feet, where the plane will fly, the wind is blowing from the west at a speed of thirty miles an hour. This is a *tail wind,* and it will help the plane as it speeds east. A *head wind,* or one blowing in the opposite direction, would hold the plane back somewhat. As the plane flies along, more weather reports will come in by radio. If the weather gets bad, the flight plan can be changed.

Once in their seats, the pilot and co-pilot give the controls one last check. Then they signal to the mechanics that everything is all right. The pilot looks at the *wind direction indicator.* This indicator shows the direction of the wind over the ground. The concrete runways, each about a mile long, are arranged like the spokes of a wheel. The controller tells the pilot what runway he can use so that he can take off into the wind. Then he releases the brakes that keep the landing wheels from turning. The plane taxies to the end of the runway and swings around into the wind.

Here the plane waits. It cannot take off until the *controller* or *dispatcher* in the *control tower* says so. The controller is the traffic "cop" of the airport. From the control tower, he can see all the runways. He is in touch by radio with all planes on the ground or in the air near the airport. To prevent accidents, no plane is allowed to land or take off unless he says that the runway is clear.

"Cleared for take-off!" says the controller over the radio. This means that the pilot can take off. No other planes are coming in or going out. A loud roar comes from the engines, and the plane trembles as the pilot opens the throttle. He lowers a set of wing flaps between the ailerons and the fuselage on the rear edges of the wings. They give the plane extra lift so that it can take off with a shorter run along the ground.

From your seat by the window, you can see the ground moving swiftly backward. The plane is speeding down the runway. Then the ground seems to drop slowly away. The plane is in the air! But the take-off was so smooth that you did not even notice it.

The pilot moves a lever, and the wheels of the landing gear are pulled up into the wings. This helps to reduce the *drag,* or backward push of air on the plane. Drag cuts down speed. So everything is done to keep drag as small as possible. The smooth surface of the plane helps reduce drag.

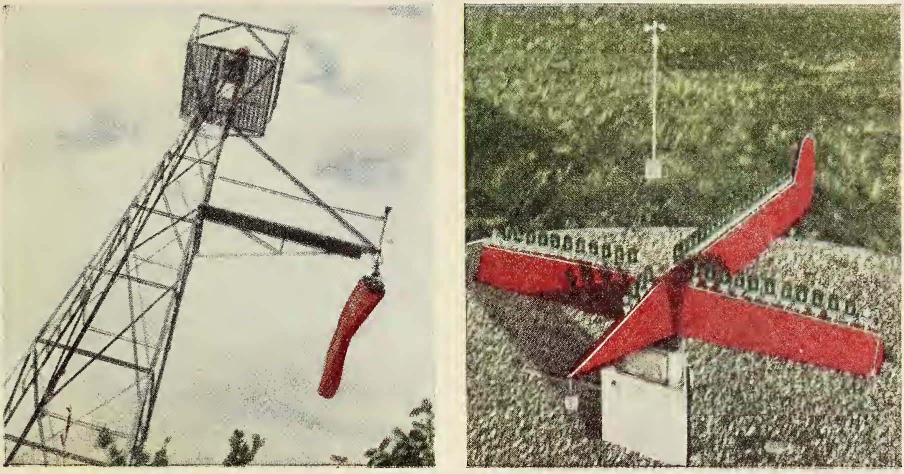
Still climbing, the plane heads east at about 250 miles an hour. When it reaches 17,000 feet, the automatic pilot is connected. This is a machine that moves the controls and keeps the plane flying in the direction set by the pilot. It leaves the pilot and co-pilot free to watch their instruments and keep in touch with radio stations on the ground.

At 17,000 feet above the earth, the air is very thin and cold. The temperature has fallen more than sixty degrees! You could not breathe this air comfortably for very long. So the airtight cabin is supplied with warm air such as you breathe on the ground. To do this, two superchargers are used. High up in the air, more than three miles above the earth, the plane can go faster because the thinner air causes less drag. Then, too, at this height, the plane can fly above much bad weather with its clouds, fog, ice, snow, sleet, and rain.

Next to fog, ice is probably the greatest danger to flying. In one minute, enough ice can form on the wings, tail, and propeller blades to make a plane lose height rapidly. Of course, the ice makes the plane heavier. But that is not the worst thing it does. It spoils the shape of the wings, and this reduces the lift.

To keep ice from piling up, the front edges of the wings and the tail have *de-icers* made of rubber. Air pumped into the de-icers makes them bulge and crack the ice. Then the ice is blown away by the rush of air. Some de-icers are heated by electric current. A liquid that is sprayed on the propeller blades keeps them free of ice.

Now the stewardess is serving your supper on a tray. You notice that it is getting dark outside. Soon you can no longer see the ground. Far below, there are only the lights of cities and towns. The pilot turns on the running lights. These are a



The picture on the left shows a beacon tower. Hanging off at one side is a wind sock. *A wind sock is a hollow canvas tube that shows which way the wind is blowing. The picture on the right shows another kind of wind direction indicator. It is called a* wind tee *and is on the ground at the airport. It turns with the wind like a weather vane and at night it is lighted so that it can be seen from the air.*

green light on the right wing, a red light on the left wing, and a white light on the tail. The lights help prevent accidents in the dark. They also show which way a plane is heading.

Are you wondering how the plane can fly on its way when the ground cannot be clearly seen? The compass in the pilot's cabin shows the direction in which the plane is heading. The main airways are marked with light beacons about ten miles apart. A beacon is usually a high steel tower with one revolving light and two fixed lights. The fixed lights flash a signal in code every ten seconds. The signal gives the number of the beacon. This tells the pilot where his plane is. Other light beacons mark tall chimneys, electric power lines, and mountain tops.

But sometimes the light beacons are hidden by clouds or fog. Then the pilot must depend on the *radio beam* along the airway. On one side of the beam, he hears the code signal for A (· –). On the other side, he hears the code signal for N (– ·). When a plane is right on the beam, a steady hum is heard. If the plane gets off the beam, the pilot hears the code signal for A or N. Over an airport, there is either no sound or the code signal for Z (– – · ·). By listening to the radio signals, a pilot can tell where his plane is at all times.

Now as you look down, you can see the bright glow of New York City.

The stewardess tells you to fasten your safety belt again. The plane is gliding down toward the airport. You can see the lights that mark the runways. The plane circles around the airport until the pilot gets the all-clear signal from the dispatcher in the control tower. Then he lowers the landing wheels and turns on the landing lights in the front edges of the wings. The plane is now heading into the wind toward a runway.

As the plane nears the ground, the pilot lowers the wing flaps again. These act as a brake on the air and slow the plane down. The landing wheels and the tail settle down on the runway with hardly a bump. As the plane rolls along, the pilot puts on the wheel brakes very gently. Slowing down all the time, the plane taxies up to the administration building and stops. The steps are rolled up to the plane, and the cabin door is opened.

You are in New York! In about three hours, you have traveled over 700 miles. On a train this trip would take five or six times as long.

1. *Make a list of the things that are done before a plane takes off on a long trip. Then explain why each one is important.*
2. *Why do pilots need the very latest weather reports?*
3. *What things are done to make airplane trips safe and comfortable?*
4. *Tell what you have learned about each of these.*

Wind direction indicator *Dispatcher or controller* *Drag*
Light beacon *Radio beam* *Wing flaps* *Control tower*
Head wind *Tail wind* *De-icer* *Running lights*

QUESTIONS TO ANSWER

1. Why are airplanes now used more than balloons?

2. List the main parts of an airplane and then tell what each part does.

3. What is still the greatest danger in airplane travel? Explain your answer.

4. Look at the picture on page 215. Why are these children running with their kites? Explain what makes a kite go up into the air and what makes it stay there.

5. How is an airplane like a bird? How is it different from a bird?

6. Many people think that helicopters will someday be the commonest kind of airplane. Why do you suppose they think so?

7. What advantages does airplane travel have over travel by train or boat? What are some disadvantages of airplane travel?

8. Why are airplanes built from light but strong materials?

THINGS TO DO

1. Collect pictures of different kinds of airplanes and bring them to school. Tell your class what you have learned about each kind.

2. Make a model airplane or a glider. Use your model to show some of the things that you have learned.

3. Look in newspapers and magazines to find some of the latest developments in airplanes. Then make a report to your class.

4. Use an electric fan and a small toy wagon to show how an airplane propeller drives an airplane. Set the fan in the wagon so that the blades are toward the rear. Turn on the fan and watch what happens.

5. Make a toy parachute. Tie several strings around the edges of a circle of cloth about one foot across. Fasten the strings to a light weight. Throw the weight high into the air and watch what happens.

6. Get a map that shows the main airways in our country. Is your city or town near one of these airways?

7. Read John Townsend Trowbridge's poem, *Darius Green and His Flying Machine.*

8. If you live near an air field or an airport, perhaps you can visit it. Then you may want to make a model of an air field or an airport. You can show this to your class.

9. Read about the Montgolfier brothers and the first balloons.

10. Find out how high airplanes have flown. Also find out how far they have flown without stopping.

11. Read more about the Wright brothers. Also read about Samuel Langley, Octave Chanute, and others who worked with the first flying machines.

12. Find out how Admiral Byrd and Roald Amundsen used aircraft to explore the polar regions. Make a report to your class.

13. Write a story about an imaginary trip across our country in an airplane. Tell what the pilots do, how they use their instruments, what the weather reports tell them, and any other interesting things you can think of.

14. Learn about airships or dirigibles. Find out what happened to the *Shenandoah*, *Macon*, *Akron*, and *Hindenburg.*

★ *In Unit Nine You Will Learn* ★

- ★ *What the parts of a flower are* ★ *How flowers make seeds* ★
- ★ *How new plants are made from parts of plants* ★
- ★ *How plants without flowers make new plants* ★
- ★ *Where new animals come from* ★
- ★ *How animals take care of their young* ★
- ★ *Why the earth is not overrun with plants and animals* ★
- ★ *Why we should help conserve living things* ★

★ UNIT 9 ★

Where Do New Plants and Animals Come From?

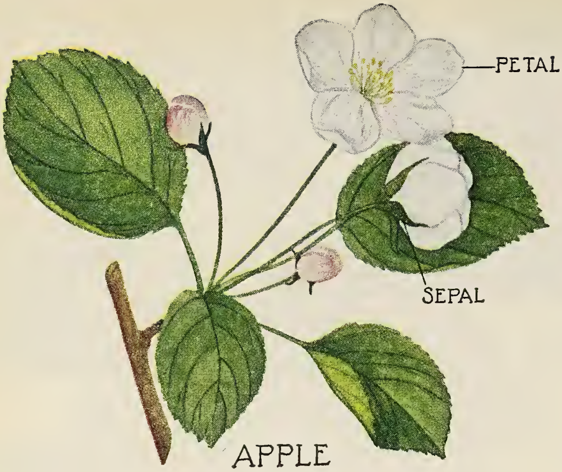
A LONG TIME AGO, people had queer ideas about where new plants and animals come from. You will probably laugh at some of their ideas. They thought that frogs and toads were made from mud at the bottom of creeks and ponds. They believed that insects came from the dew on leaves. They even thought that mice were made from piles of old rags and that fish were made from water!

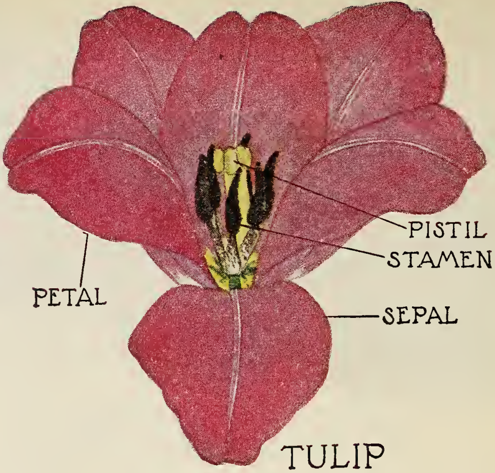
Why do you suppose that people had such queer ideas? They believed these things because they did not know much about living things. These people had no microscopes. So they never saw some of the things that anyone can see today. People of those times did not do experiments, either. They just guessed at things, and they never really tried to find out whether their guesses were correct.

When scientists began to study living things, they soon found out how foolish some of the old ideas were. They studied the structure of plants and animals, and they did experiments to see if they could discover how new plants and animals are made. Here is the important thing that scientists discovered. Every living thing comes from some other living thing.

Living things cannot come from non-living things. Frogs and toads cannot grow from mud. Insects cannot grow from dew. And mice cannot grow from old rags, nor can fish grow from water. Whenever a new plant or animal starts growing, some part of a living thing has started it growing.

Suppose that you get a shovel full of soil from the woods. Put it in a box in your schoolroom window and keep the soil moist. You may be surprised to see what happens. Some boys and girls in one class did this. After about a week had gone by, some green plants began to grow up from the soil. Do you know where they came from? In this unit, you will learn the answer to this question. You will also learn where other living things come from.





What are the parts of a flower?

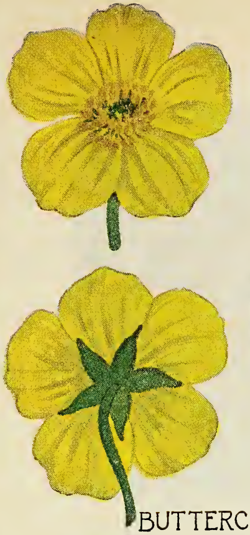
We grow flowers in our gardens just because flowers are beautiful, and we all enjoy looking at them. But flowers are important not only because they help make our world beautiful. They are more important to us and to plants for a very different reason. Flowers make the seeds from which more plants of the same kind will grow.

Before you can understand how a flower makes seeds, you need to learn what parts a flower has and what these parts do. Look at the pictures of the apple blossoms and the tulip on this page. Study these flowers to find the different parts.

Probably the first thing that you notice is the pink and white portion of the apple flower. This is made of several parts, as you can see. Each of these parts is called a *petal.* The petals of flowers usually have bright colors. Now look at the petals of several other flowers. You can find red, yellow, blue, purple, and orange petals. Some have more than one color.

Notice the thin, green parts on the outside of the bud in the picture. These parts look like small leaves. Each of these parts is called a *sepal.* When a flower is still a tight bud, the sepals cover the petals snugly. As the bud swells and opens, the sepals separate and then fold back. They have protected the colored petals and the other parts inside until the flower opened. Sepals are usually green. But some flowers, such as tulips, have sepals with different colors.

The petals and the sepals seem important to us, because they make the flower beautiful. But the small parts inside the petals are far more important to the flower. In the center of most flowers, you can see a little stalk.



BUTTERCUP

LILY

POPPY

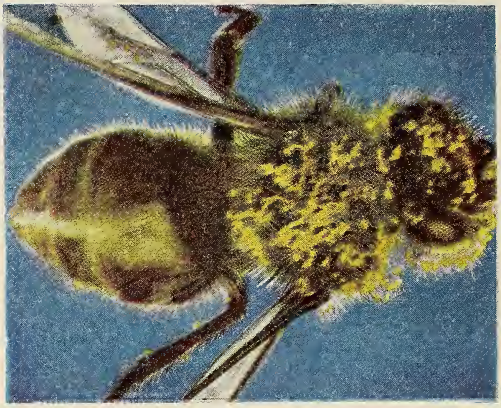
This is called the *pistil.* Around the pistil is a circle of little slender parts. These are called *stamens.* Find the stamens and the pistil in the picture of the tulip.

Some flowers have only one pistil, but others have more than one. In some flowers, the stamens are longer than the pistil. In others, they are shorter. Many of the flowers you know have all four parts—petals, sepals, pistils, and stamens. But some flowers have pistils and no stamens. Others have stamens and no pistils.

Look at as many different spring flowers as you can. Find out whether they have petals, sepals, pistils, and stamens. Right now, you can probably see the flowers of daffodils, hyacinths, lilies, and tulips. You can also see the blossoms on apple, cherry, peach, and pear trees. Choose some one flower and look at the pistil and the stamens very carefully.

If you rub your finger over the stamens, you will find something that looks like yellow dust. This is called pollen, as you have learned. It is very important in making seeds. If you can look at some pollen with a microscope, you will see that it is made of tiny grains. You will also find that these grains have many different shapes. Pollen of one kind of flower is shaped differently from pollen of another kind of flower. The picture on the next page shows how the pollen grains of the sunflower look under a microscope. Other pollen grains may be round.

Flowers cannot make seeds without pollen grains. The pollen grains must land on the top of the pistil. This part of the pistil is called the *stigma.* If you touch the stigma of a flower, you will find that it feels sticky. The sticky stigma helps the flower get pollen to make seeds.



Pollen gets from the stamens to the stigma in several ways. In some flowers, the stamens bend over and touch the stigma. In others, the stamens are taller than the pistil. So the pollen grains fall on the stigma. Wind also carries pollen from one plant to another. Of course, many of the pollen grains fall to the ground. But some of them are blown against the sticky stigma of the pistil in another flower.

You have probably seen bees and other insects flying from flower to flower. They crawl into the flowers to get nectar and pollen. As they do this, some of the pollen sticks to their bodies. Pollen grains picked up in one flower are brushed off on the stigma of another flower. The picture of the bee on this page shows how pollen sticks to the hairs on bees. The bees carry it from flower to flower. Carrying pollen in this way is the most helpful thing that insects do.

Many flowers will make better seeds if the pollen comes from another flower of the same kind. Pollen grains from a rose will not make geranium seeds if they are carried to the stigma of a geranium flower. To make seeds, a flower must get its own kind of pollen. But pollen grains from one rose will make good seeds if they fall on the stigma of another rose.

---

1. *What are the main parts of a flower?*
2. *How do sepals help flowers?*
3. *How does pollen get from the stamens to the pistil of the same flower?*
4. *How does pollen get from one flower to another?*
5. *Why is it important for flowers to make seeds?*

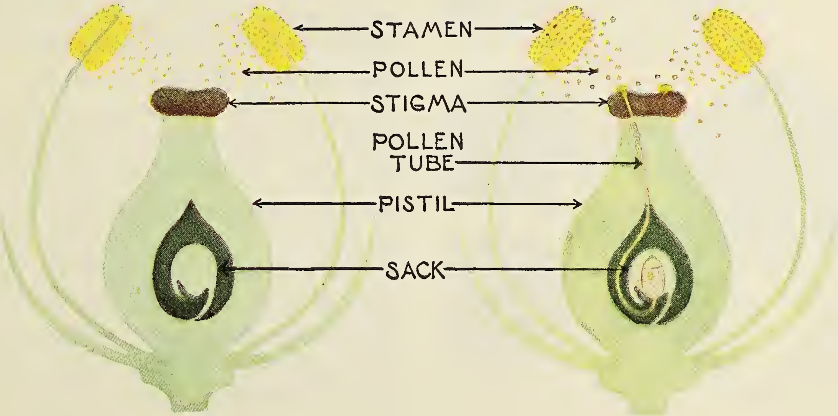
How do flowers make seeds?

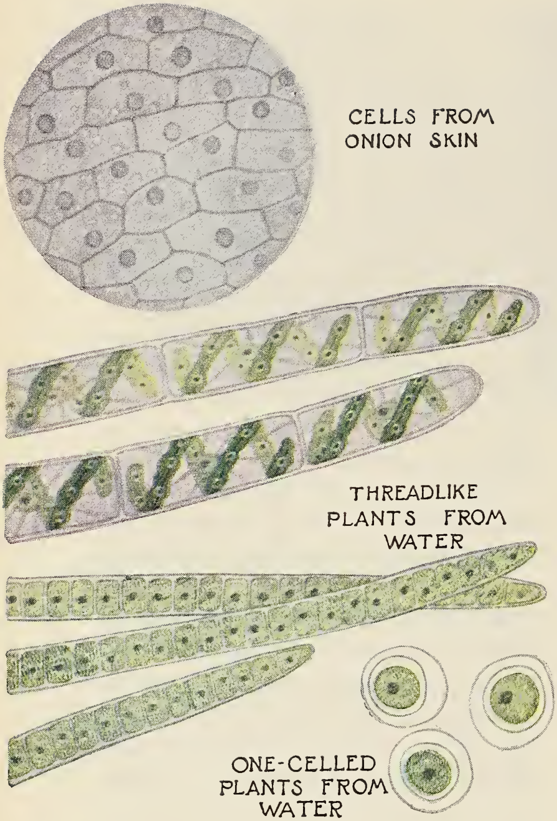
Now that you know what the structure of a flower is, you can understand how flowers make seeds. You cannot watch what is going on inside the millions of flowers each spring and summer as they make the seeds for next year's plants. But you can learn some of the things that scientists have discovered about how flowers make seeds.

Soon after a pollen grain lands on the sticky stigma, the grain begins to grow. But it does not get bigger around like an apple or an orange. It grows by sending out a tiny tube. This tube pushes its way down into the pistil. It keeps on growing and pushing until it gets to the bottom. In the bottom of the pistil are one or more tiny sacks. These sacks are much too small for you to see without a microscope. Look at the picture on this page. You can see that the pollen tube has grown into the bottom of the pistil.

In each sack at the bottom of the pistil, there is a tiny egg! Probably you did not know that plants have eggs, but they do. The egg can grow into a new plant, just as a hen's egg can grow into a new chicken. But the plant eggs cannot grow into new plants without the help of pollen grains. When part of a pollen grain joins with the egg, the egg begins to make a new plant.

Before you can understand how this happens, you need to remember something important about all living things. Every living thing is made of cells. Your body is made of billions of cells. They are like tiny building blocks that are all put together to make your body. If you have a microscope, you can look at different parts of living things and see some cells.

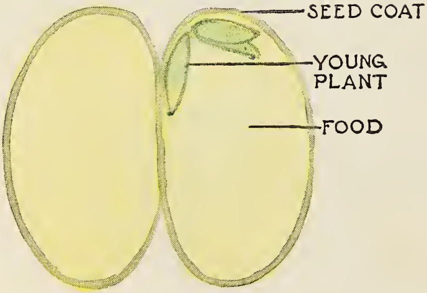




CELLS FROM ONION SKIN

THREADLIKE PLANTS FROM WATER

ONE-CELLED PLANTS FROM WATER



Get a piece of thin skin from an onion. Look at it through a microscope. Can you see the cells in the onion skin? Then try to get some green threadlike plants that float in water. Look at them with the microscope, too. Do the things you see look like those in the pictures on this page? Can you find the tiny cells in the water plants?

What you know about cells will help you understand how a seed is made. Inside the pollen grain are several cells. And inside the tiny sack at the bottom of the pistil, there are also several cells. One of the cells in this sack is the egg. A cell from the pollen grain joins with the egg cell. When these two cells join, a new cell is made.

The new cell begins to grow. At first, it just gets bigger. Then after it gets to a certain size, it divides and makes two cells. These two cells grow bigger for a while. Then they divide to make four cells. These cells keep on growing and dividing to make more new cells. These new cells make the tiny new plant.

The tiny plant is growing inside the little sack that held the egg. Around this plant, the other cells in the sack are also growing and dividing. Some of these cells make the food that is stored around the young plant. Other cells make a covering for the plant and its food. This covering is called the *seed coat*. It protects the young plant and its food.

The little sack with its egg has become a seed. The seed has these three parts.

1. The tiny new plant.
2. The food stored around the plant.
3. The seed coat that protects the plant and its food.

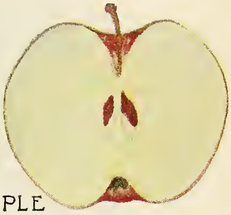
Most flowers make more than just one seed. Some of them make a great many seeds. Where do you find the seeds? If you are looking for the seeds of a bean plant, you pick the pod and open it. The seeds, or beans, are inside the pod. When you cut into an orange or an apple, you find the seeds inside.

Scientists have a name for the part of any plant that contains the seeds. They call this part the *fruit*. The fruit is the lower part of the pistil that gets bigger while the seeds are being made inside it. You know that apples, oranges, cherries, and peaches have seeds. So, of course, they are fruits.

But you may be surprised to learn that tomatoes, cucumbers, pumpkins, and bean pods are also fruits. They have seeds in them. So scientists call them fruits, too. Look at the pictures on this page. You will see some of the different kinds of fruits. Each fruit contains seeds that will grow into new plants. And each new plant will make seeds and fruits, too.

If you have ever made a garden, you have watched seeds grow into new plants. You plant a seed in the soil. After it is moistened by the rain

PEA POD


APPLE

TOMATO

CUCUMBER

HICKORY NUT

PLUM

PETUNIA

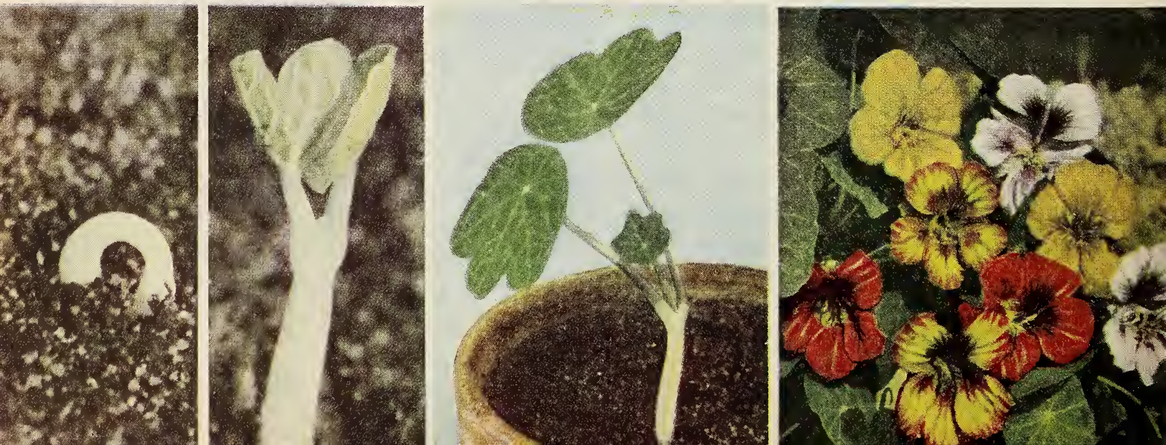
and warmed by the sun, the seed sprouts. The tiny plant in the seed begins to grow. It grows by making millions of new cells. At first, it uses the food that is stored in the seed. It sends down roots, and it pushes its stem up through the soil. When the stem gets aboveground, leaves unfold. Then the green leaves begin to make the food that the plant needs. The plant keeps on growing. At last, it is a big plant like the one that it came from. It has flowers. So it can make seeds and fruits, too.

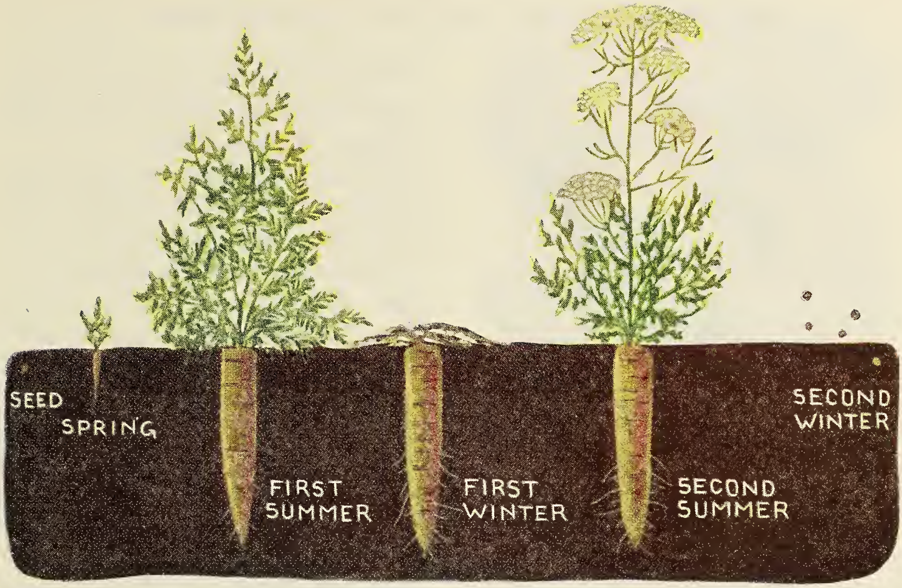
Some plants, such as trees, keep on growing and making seeds for many years. Many trees are hundreds of years old. You have probably seen pictures of the huge trees that grow in California. Some of these giant trees began to grow nearly 4000 years ago. But most plants do not live so long as trees do. If you have ever made a flower garden, you know that some plants live only a year. These plants are called *annuals*. An annual plant has flowers and makes seeds. Then it dies during the winter. Petunias, California poppies, zinnias, sunflowers, marigolds, and verbenas are annual plants.

There are also plants that live two years and then die. During the first year, they grow roots, stems, and leaves but no flowers. During the second year, they have flowers and make seeds. Then they die. Plants that do this are called *biennials*. Some biennial plants are Canterbury bells, English daisies, forget-me-nots, foxgloves, hollyhocks, cabbages, turnips, and beets.

Plants that live for more than two years are called *perennials*. Of course, trees and shrubs are perennials. Perennial plants, except trees and shrubs, die down to the ground during the winter. Then in the spring, they start to grow again. Perennials are often planted in flower gardens, because they last for many years. Some of the common perennials are

A nasturtium plant comes up from a seed, grows, makes flowers and seeds, and dies in one year. What kind of plant is it?





Look carefully at this picture. What kind of plant is a carrot?

narcissus, tulip, iris, phlox, primrose, delphinium, and bleeding heart. Most kinds of grasses that we use for lawns are perennials. If a lawn is well cared for, the grass will grow for many years.

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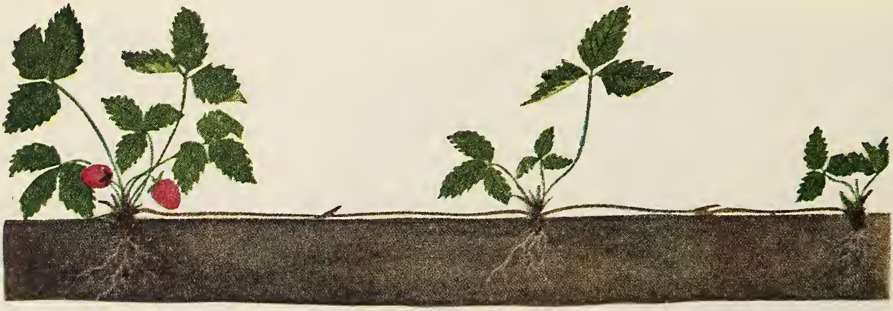
1. *Here are some of the things that happen when a flower makes a seed, but they are not in the order in which they happen. See if you can put them in the right order.*
   - *a) A pollen grain lands on the stigma.*
   - *b) The flower makes pollen.*
   - *c) The pollen grain begins to grow a tiny tube.*
   - *d) The seed is fully grown.*
   - *e) The pollen tube reaches the egg.*
   - *f) A cell in the pollen grain joins with a cell in the egg.*
   - *g) The new cell grows and divides to make more cells.*
2. *What are the three parts of a seed? What does each part do?*
3. *How do scientists use the word* fruit? *Give some examples to show that you understand this use of the word.*
4. *What do we call plants that live only a year? Only two years? More than two years? Give an example of each kind of plant.*

How are new plants made from parts of plants?

SUPPOSE THAT you have a plant and want to grow a new plant from it. But you do not want to wait until the plant has flowers and makes seeds. How can you get a new plant? That depends on what kind of plant it is. If the plant is a geranium or an ivy, you can grow a new plant from a *cutting.* A cutting is a piece of a plant that will grow into a new plant. It is usually a piece of the stem. Geraniums, ivy, and many other plants will grow from cuttings.

If you follow these directions carefully, you can grow an ivy plant from a cutting. Use a sharp knife to cut a piece of stem from a growing ivy plant. The piece should have two joints, one near the top and the other near the bottom. Plant the ivy cutting in sand so that the lower joint is covered. Set the cutting in a light place but not in the sun. Keep the sand moist. It may take several weeks for the new leaves and roots to start growing. If you put the cutting in water instead of sand, you can watch the roots begin to grow.

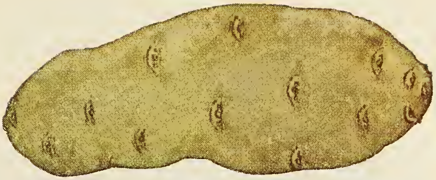
When the new leaves and roots are growing well, plant the cutting in a pot of soil. You will soon have a good-sized ivy plant that grew from a piece of the stem from another ivy plant. You can also make cuttings from other plants and grow them. Try cuttings from geraniums, grapevines, willows, and poplars. Put them in

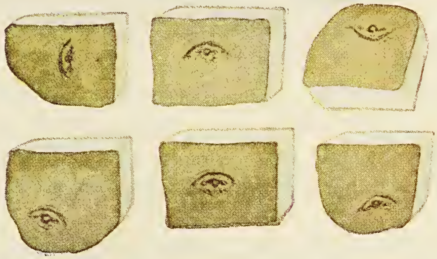


moist sand or water as you did the ivy cutting.

Some plants send out stems that grow along the ground. These stems are called *runners.* When a runner touches moist soil, it may send roots down into the soil at certain places. As the roots grow down into the soil, new stems and leaves grow up into the air. Soon a new plant is made. The picture at the bottom of page 250 shows a strawberry plant that makes new plants in this way.

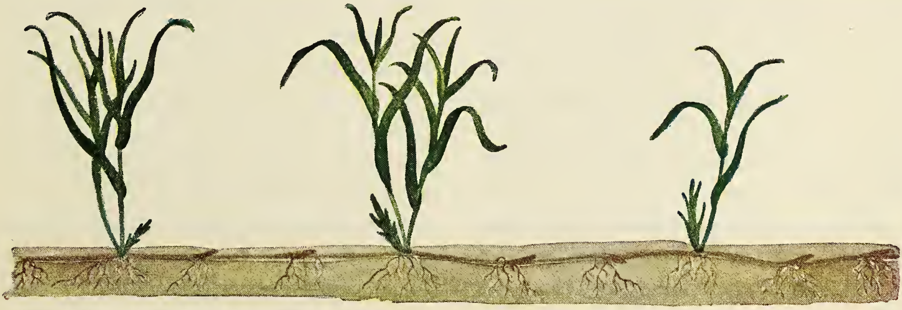
The vegetable that we call a white potato is really a thick stem that grows under the ground. Do you see the "eyes" in the picture of a potato on this page? The eyes are really buds on the stem. The inside of the potato has food for the buds to use when they begin to grow. We use this food, too. The potato in the picture has been cut into pieces for planting. Each piece has an eye, or bud, and enough food to start it growing.

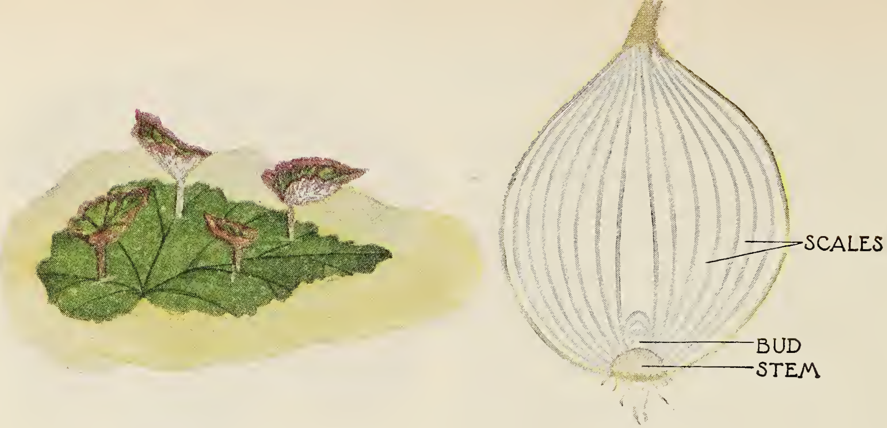




Do this experiment to find out how potatoes are grown. Put a white potato in a jar of water. Only one end should be covered with water. Watch the potato for a few weeks. What happens at the eyes of the potato? Why is the potato shriveling and getting smaller?

The picture below shows another way that plants make new plants from stems. Quack grass sends out stems under the ground. New plants grow from these stems. Even if the stems break off from the plant, new plants will grow from them. Some of the weeds that cause the most trouble in gardens and on farms make new





One begonia leaf can make several new plants if cuttings are made in this way. The layers around the bud in an onion bulb are really leaves called scales.

plants in this way. Unless the stems are pulled out of the ground, they will keep on making new plants.

New quack-grass plants will grow from roots, too. You can see why it is hard to get rid of plants like this weed. Many other plants will also grow from roots. Sometimes the stems of raspberry bushes or barberry bushes are cut down to the ground. Then the roots make buds and send up new stems. People who grow some kinds of roses, raspberries, and blackberries get new plants from the roots. They cut the roots into small pieces and plant them. The pieces are called *root cuttings.* After a while, the root cuttings make buds and send up stems. Phlox and oriental poppy plants can be grown from root cuttings, too.

Even the leaves of some plants can make new plants. Get a leaf from a begonia plant. Make a cut across each of the big veins of the leaf and lay it on moist sand. Cover the edges of the leaf with sand and keep the sand moist. The leaf will soon begin to send tiny roots into the sand. If the leaf is left on the sand, tiny stems will also come up from the edges of the cuts in the leaf.

Sometimes a new plant grows from what is called a bulb. This bulb is really a bud that grows under the ground. You can look at a bulb to see how a new plant can grow from it. Get an onion bulb and cut it in two. In the center of the bulb, you can see a tightly folded little bud. Notice the many layers that are around the bud. They are stored food that the bud uses to help it grow into a new plant. Peel off several of these layers and look at them.

Daffodils, hyacinths, lilies, and tulips are grown from bulbs. You can plant some flower bulbs and watch them grow. Put the bulbs in a dish and pour pebbles around them. Keep the pebbles moist. Roots will grow down around the pebbles, and stems and leaves will grow up into the air. Soon the plants will have flowers. You will probably be surprised to see how fast the plants grow and bloom. Many early spring flowers come from bulbs.

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1. *Name all the parts of a plant that can grow into a new plant. Then give an example of a plant that grows from each part you have named.*
2. *Why are weeds like quack grass hard to get rid of?*
3. *How could you grow a new geranium plant without planting seeds? A new blackberry bush?*
4. *When parts of a potato are planted, why must each part have at least one eye?*
5. *Do all stems and buds grow above the ground? Explain your answer.*

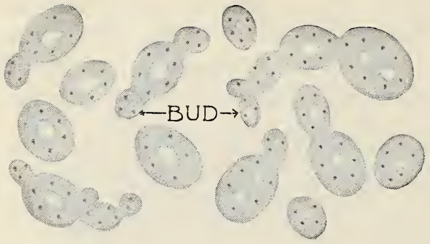
How do plants without flowers make new plants?

YOU ALREADY KNOW that many kinds of plants have no flowers. So, of course, these plants cannot make seeds. Some plants have no stems, roots, leaves, or bulbs, either. They must make new plants in other ways. You have learned what some of these ways are.

In Unit Four, you found out how bacteria multiply by dividing. Each of these very tiny plants is made of just one cell. To make more bacteria, the cell grows bigger and then splits into two smaller cells. These soon grow to full size, and then each one divides again. This goes on and on, and it happens very quickly. You remember that some bacteria grow to full size and divide in twenty minutes. Bacteria make more new plants in a very simple way.

Besides bacteria, there are other kinds of very tiny plants. Some of these plants are called yeasts. These plants are so small that you cannot see them with the naked eye. If you look at a yeast plant with a microscope, you will see that the plant has no stem, roots, or leaves. It is made of just one cell. Of course, it has no flowers or seeds. How does a yeast plant make new yeast plants?

You can easily grow some yeast plants. A yeast cake has thousands of tiny yeast plants in it. These are mixed with flour and pressed into a cake. The plants are still alive. They will start growing if you give them



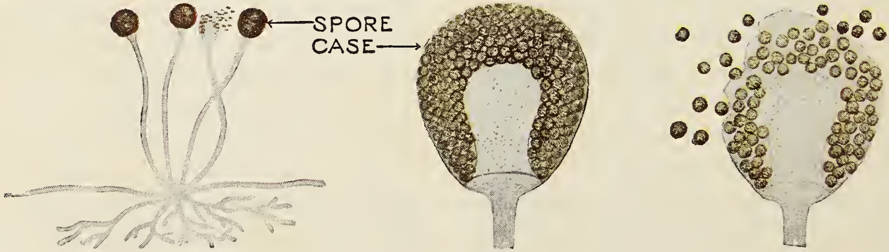
the right kind of food. They must also be kept moist and warm. Follow the directions carefully.

Fill a test tube or a small bottle about three-fourths full of warm water. Crumble a piece of yeast cake into the water. Then add a teaspoonful of sugar for food. Put a cork lightly in the tube or bottle. Then shake the tube or bottle until the yeast and sugar are thoroughly mixed. Set it in a warm place for a few hours and watch to see what happens. Does the cork pop out? Can you see bubbles in the water? These bubbles are carbon-dioxide gas, and they may push the cork out. When yeast grows, it gives off carbon dioxide.

If you have a microscope, you can watch these yeast plants grow. Look at the picture on the left. Do you see little swellings on some of the plants? These swellings are called *buds.* The buds break off and grow into new yeast plants. So we say that yeast makes new plants by *budding.* But do not get the idea that the buds on yeast plants are like the buds on green plants. Flowers or stems grow from the buds of green plants. But yeast buds are just little bits of the plant that push out, break off, and then grow into new yeast plants.

Many plants without flowers make new plants in still another way. Ferns, mosses, seaweeds, molds, and mushrooms have no flowers or seeds. The new plants grow from spores. To find out more about spores, you can grow some bread mold.

Moisten a slice of bread and lay it in a dish. Then shake a dusty cloth over the bread. Cover the bread with another dish and put it in a warm place for a few days. What happens? As soon as the mold plants are growing well, look at them carefully. Use a magnifying glass or a microscope if you have one. You will see that hun-



dreds of tiny threads have grown over the bread. Notice the tiny black balls on the ends of some of these threads. These tiny balls are called *spore cases.* They hold the spores that can grow into new bread-mold plants. The pictures on Page 254 show you what the spore cases look like.

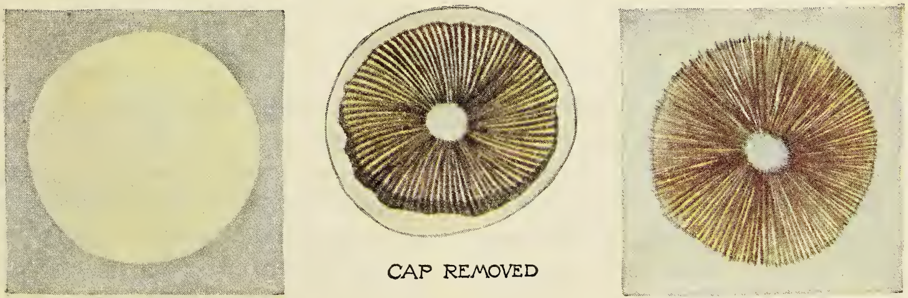
Touch some of the mold and then look at your finger. The tiny bits that look like dust are really large numbers of spores. When you touched the mold, some of the spore cases burst open. The spores stuck to your finger. Now blow them off. They are so small that you cannot even see them in the air. When spore cases are ripe, they break open. Then the slightest breeze will carry some of the spores away through the air. Millions of spores float away in the air, but only a few find a good place to grow.

Spores are very different from seeds. They are not at all like seeds on the inside. But spores act like seeds, because they can grow into new plants. Probably there are many spores in the room where you are right now. You found that you could easily catch some spores and make them grow. You did not even know that you were catching them, because they were so small that you could not see them.

There are many different kinds of molds. Some kinds grow on fruit. Others grow on vegetables. Still others grow on almost anything that is damp. There are blue molds, black molds, red molds, and green molds. All of them grow from spores. They belong to a group of plants called fungi. Puffballs and other mushrooms belong to the same group.

Mushrooms grow from spores, too. On the underside of some mushrooms, there are little folds. Spores grow on these folds. When the spores are ripe, they fall to the ground. Then they grow into new mushroom plants, just as mold spores grow into new mold plants.

One spore is too tiny to see. But you can see many of them together if you make a spore print as suggested on the next page.



CAP UPSIDE DOWN ON PAPER

CAP REMOVED

SPORE PRINT ON PAPER

Perhaps you can find some mushrooms in the fields or woods. Bring them to class and lay them carefully on a sheet of paper. In a few hours, you may see that hundreds of spores have dropped from the mushrooms onto the paper. If you crush a puffball, you will see many spores.

Did you ever see the underside of a fern leaf? There are rows of little yellow-brown dots on it. Some people think these harm the plants. So they pick off the dots, which are really little spore cases. Even though ferns are green plants, they do not have seeds. They have spores that grow in the little cases on the underside of the leaves. When the spores fall on moist soil, they can grow into new fern plants. Mosses and seaweeds are other kinds of green plants that grow from spores instead of seeds.

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1. *What is a very simple way in which new living things are made?*
2. *How do yeasts make new plants like themselves?*
3. *How is a spore like a seed? How is it different from a seed?*
4. *Name four different kinds of plants that grow from spores.*

Where do new animals come from?

NOW YOU KNOW where the millions of new plants come from each year. There are several different ways in which new plants are made. But there is one thing that is the same in each of these ways. Whenever a new plant is made, some part of an old plant is used to make it.

Seeds, stems, roots, leaves, and bulbs all come from plants. Spores are made by plants, too. All these things can grow into new plants. Bacteria and yeasts make new plants from parts of themselves. Every plant comes from some part of another plant of the same kind.

A female spider protects her eggs with a silken case like the one in the picture at the left. A bird has laid her eggs in this nest among the reeds.

But how do animals make more of their own kind? You know that some animals hatch from eggs and others are born alive. But they are all like plants in one way. They all come from some other living thing. Whenever a new animal starts growing, part of a living animal has been used to start it growing. It has to have other animals of the same kind for its parents.

You remember the six main groups of animals—mammals, birds, reptiles, amphibians, fish, and insects. Which of these hatch from eggs laid by the mother? And which are born alive? Of course, you know that birds come from eggs. After the female bird lays the eggs in the nest, she sits on them to keep them warm. Sometimes the male bird and the female bird take turns sitting on the eggs.

Surely you have seen a broken hen's egg. You know that inside the shell there are two parts. The yellow part in the middle is called the yolk. Around the yolk is the white part called the white of egg. In the yolk of the egg is the tiny cell that will grow into a chicken. This cell is so small that you cannot see it without a microscope. The eggs of all birds have the same parts as a hen's egg.

As the mother bird keeps the eggs warm, the tiny cell in each yolk grows bigger and divides into two cells. Soon each of these cells divides, and then there are four cells. The four cells divide to make eight cells, and so on.

This goes on until there are millions of cells. These cells are all joined together to make the young bird. At last, it cracks the shell and comes out. All the time that the cells are dividing, they are using the yolk of the egg for food.

Every living thing begins its life as one little cell. It grows by dividing into more and more cells. The picture on this page shows how a frog's egg divides into two cells, then four, then eight, and so on until a tiny tadpole is formed. The tadpole keeps on growing as the cells in its body go on dividing.

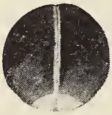
You know that frogs and toads belong to the group of animals called amphibians. All amphibians hatch from eggs. The mother frog and the mother toad lay hundreds of eggs in the water. The eggs hatch into little tadpoles that do not look at all like their mother or father. But the tadpoles grow and change. At last, they are little frogs or toads that look just like their parents.

Insects are another group of animals that hatch from eggs. The female of some kinds of insects lays hundreds of tiny eggs that hatch into little wiggly larvae. A caterpillar is the larva of a butterfly or a moth. It looks more like a worm than it does like its parents. After the larva has grown, it becomes a *pupa*. From the pupa comes the full-grown insect.

The eggs of other kinds of insects hatch into little creatures that look much like their parents except that they have no wings. You remember that a grasshopper egg hatches into a small grasshopper without wings. The little grasshopper grows and changes until it is a full-grown grasshopper with wings.

Perhaps you have seen fish eggs in the water. One female fish may lay thousands of eggs. You will usually find fish eggs in a shallow part of a stream, pond, or lake. Every egg has a tiny cell with food around it. The eggs hatch into young fish. But some kinds of fish are born alive. Many kinds of sharks and all guppies are born alive. If you have an aquarium in your schoolroom, you may have some guppies in it. Perhaps you have seen the young guppies as they were born.

Nearly all reptiles hatch from eggs. Turtles, alligators, lizards, and crocodiles all come from eggs. Each egg has a tiny cell with food around it. Perhaps you have found turtle eggs in the sand near a stream or lake. Many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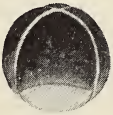
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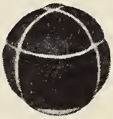
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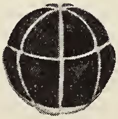
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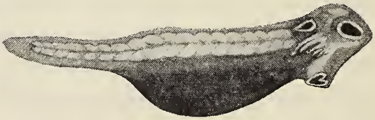
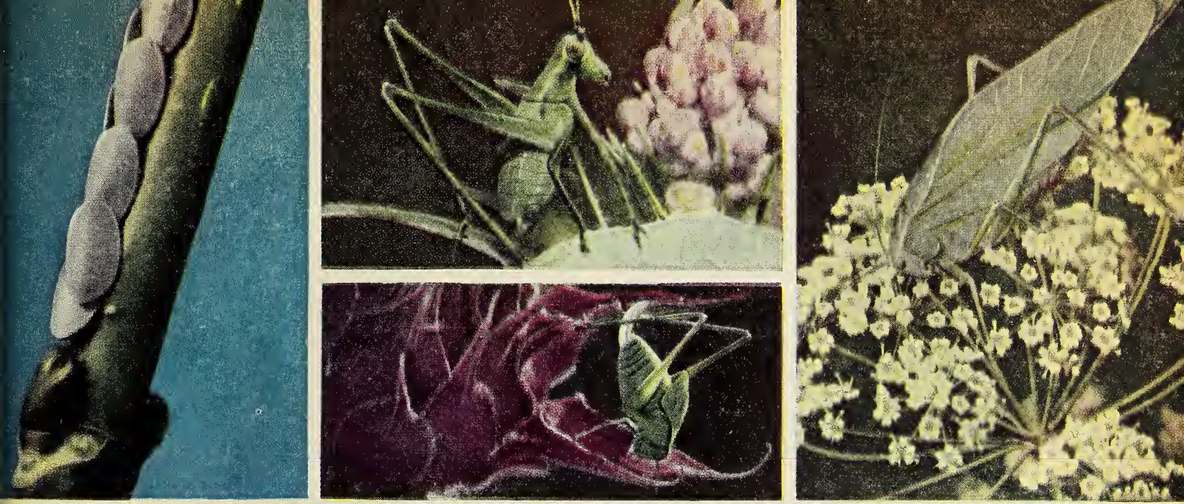

BEGINNING OF TADPOLE



These pictures show how a katydid grows from an egg like one of those in the first picture. How is a katydid like a grasshopper in the way it grows?

kinds of snakes hatch from eggs, but some kinds of snakes are born alive.

Most mammals are born alive instead of being hatched from eggs. Perhaps you are wondering whether every mammal begins its life as one cell. Yes, it does. Every living thing begins as a cell. Every mammal begins as one small cell in its mother's body. This cell divides into two cells. The cells keep on making more cells inside the mother's body until the young animal is big enough to be born. While it is growing, the young animal gets milk from its mother's body. Cats, dogs, rabbits, squirrels, horses, cows, pigs, and sheep are a few of the many kinds of mammals.

Now you know that new animals and new plants are made in much the same way. Every plant and every animal starts from a cell that is part of its parent's body. All living things are made from other living things of the same kind. If people of long ago had known this, they would not have believed such queer things about where new plants and animals come from.

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1. *How is a bird's egg like the seed of a plant?*
2. *How are mammals and birds different in the way that their young are produced?*
3. *How does every living thing begin its life?*
4. *How do living things grow bigger?*
5. *Which of these animals are born alive? Which hatch from eggs?*
   Robin Deer Frog Turtle Mouse Snake Cricket

Muskrats and opossums take care of their babies and protect them from enemies.

How do animals take care of their young?

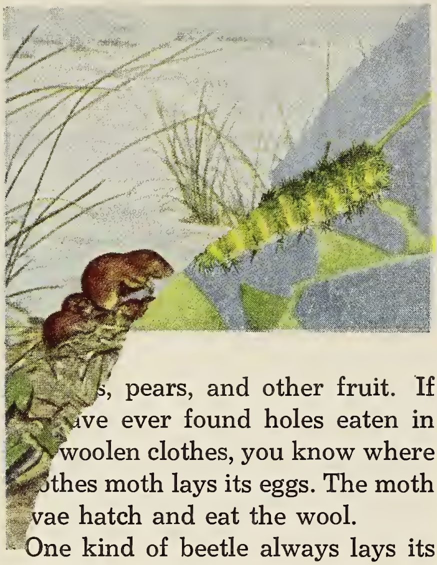
Probably you were about a year old before you could walk. You were three or four years old before you could talk clearly. When you were a baby, you could not have stayed alive without the care that your parents gave you. Even now, you would have a hard time earning enough money to buy your food and clothes and to pay for a home. Your parents still take care of you.

Many kinds of animals would die if their parents did not take care of them for a time after they are born. You know that kittens stay with their mother for several weeks. So do young dogs, horses, cows, pigs, and rabbits. Young elephants stay with their mothers for two years. All these animals are mammals. They must get milk from their mother's body, because their own bodies have not grown big enough for them to get their own food. Puppies, kittens, and young rabbits are not strong enough to walk far, and their teeth are not big enough to bite and chew. Of course, they could not protect themselves.

Black bears take care of their young for several months. When the cold weather comes, the mother bear digs a hole or finds a cave. She stays asleep in the hole or cave all winter. We say that she *hibernates.* While she is hibernating, the young bears are born. They are not much bigger than squirrels, and they are very helpless. For about two months, the mother bear covers them to keep them warm. As they drink milk from her body, they grow bigger. When they are about three months old, they come out of their hole. Even after the young bears come out, their mother feeds them until they are old enough to get their own food.

Young birds are very helpless for many days after they hatch from the eggs. The mother and father birds bring them food and keep them warm. Their parents protect them from the rain and from other animals. If a cat, a hawk, or another enemy comes near the nest, the mother and father try to drive the enemy away. The young birds stay with their parents until they grow big and strong enough to take

with plants and animals?
did
birds w r of seeds that it makes. Then
Many r that there are probably
young. M plants like it in the gar-
their eggs s ch plant is making many,
When the egg
sects must find now that the earth
course, many of the eg ies, turtles, cod-
before they can hatch ny other kind
young insects die before th of the new
But each mother insect lay ive and be-
of eggs. So there are alwa did, you
new insects growing up each y me to
There is one thing which man many
sects do that helps their young. What
lay the eggs near food so that ing
young can eat as soon as they hat
Flies lay their eggs in garbage or nts
caying meat. Cabbage butterflies la ve
their eggs on cabbage plants. Monarch ,
butterflies lay their eggs on milkweed t
plants. Codling moths lay their eggs



s, pears, and other fruit. If ave ever found holes eaten in woolen clothes, you know where othes moth lays its eggs. The moth vae hatch and eat the wool.

One kind of beetle always lays its gs near a grasshopper's nest. As oon as the beetle larvae hatch, they rawl over and eat the grasshopper eggs. The mud-dauber wasp builds a nest of mud and lays her eggs in it. Then she puts food in the nest for the wasp larvae to eat when they hatch from the eggs. So the young are well fed, even though their mother has gone away and left them.

Most fish, reptiles, and amphibians do not take care of their young. Fish, frogs, toads, and salamanders lay a great many eggs. Even though many thousands of eggs are destroyed and thousands of little fish and tadpoles are eaten by other animals, there are always young ones growing up.

There is one kind of fish that does protect its young. This fish is called the stickleback. The father builds a nest in which the mother lays her eggs. Then the father guards the nest and fights off enemies until the eggs hatch and the young fish can take care of themselves.

1. *Which groups of animals give their young the most care?*
2. *Which animals take more care of their young, those that have many young or those that have only a few?*
3. *Many insects help their young start growing. Give some examples of how they do this.*
4. *If you have ever seen a mother dog or cat taking care of her young, tell your class what you saw.*
5. *Did you ever watch a bird that was protecting its nest from enemies? Tell what the bird did.*

Why is the earth not overrun with plants and animals?

For millions of years, animals and plants have been living on earth. Each year, most of them produce young animals and plants. Billions of new animals and plants begin their lives every year. You have learned that a fly hatches from an egg and is full-grown in about eleven days. Then it can have young. One scientist figured out that in five months, starting with just one pair of flies, there would be nearly 200 billion billion flies! They would cover the entire earth with a layer forty-seven feet thick!

In the spring, a female frog or toad lays hundreds of eggs. A turtle usually lays several dozen eggs. Some snakes lay forty or more eggs each year. Birds lay fewer eggs, but a pair of robins often has several families every year. Sparrows raise several families every year, too. A female codfish lays about 9 million eggs a year. Try to find a female spider with her "egg basket" and keep her until the eggs hatch. Then you can see how many young spiders come from the eggs laid by just one spider.

Plants are also making new plants at a great rate. Billions and billions of tiny plants, such as bacteria and yeasts, are produced every hour. Other plants are also making huge numbers of seeds and spores. Go into a garden when the seeds are ripening. Choose one plant and try to count the number of seeds that it makes. Then remember that there are probably many other plants like it in the garden. And each plant is making many, many seeds.

Of course, you know that the earth is not covered with flies, turtles, codfish, bacteria, yeasts, or any other kind of animal or plant. Most of the new plants and animals do not live and become full-grown. If they did, you could not walk from your home to school. There would be too many plants and animals in your way. What happens to keep many of these living things from growing up?

As you know, all animals and plants must have certain things to stay alive and grow. All living things need air, food, water, and room to grow. Most of them need sunlight and warmth.

too. Do you think that it is easy for them to get all the things they need to live and grow? Suppose that you look at some plants and animals.

Find a garden where the plants are just coming up. You may see that the plants are crowded close together. They shade each other from the sunlight. And the roots of each plant are taking food materials and water from its neighbors. The plants are really carrying on a battle with each other for enough sunlight, food materials, and water. Many of the plants lose out and die before they are full-grown. Only the plants that live to be full-grown can make more new plants like themselves.

Now let us see what happens to some tadpoles after they hatch from eggs in the spring. Many things may keep them from becoming frogs or toads. Turtles and fish eat them. In the early spring, the pond may freeze. Or the summer sun may make the water too hot. Perhaps there is not much rain. So the pond where they live begins to dry up. This crowds the tadpoles into a smaller space. Soon there is not enough oxygen and food in the water for them all. Many of the tadpoles die. From the hundreds of eggs laid by the mother, only few tadpoles ever live long enough to become frogs or toads. And only the frogs that live and become full-grown can ever produce more frogs.

As you can see, staying alive is hard for plants and animals to do. Only a certain number of living things can live in a certain amount of space. In the battle for the things they need, the weaker plants and animals die or are killed. Only the stronger ones live. So the number of animals and plants that become full-grown is very small compared with the huge number that is produced every year. If you watch a field or a pond for several years, you will find that the number of plants and animals living in it stays about the same year after year.

Even the living things that get a chance to grow do not live forever. Some animals, such as insects, live for only a short time. They often die after they have laid their eggs. Other animals live for a few years, but some live quite a long time. Here is a list of animals. It tells how long each one may live.

Animal	*Years*
Toad	4-8
Frog	10-12
Rabbit	5-7
Cat	8-9
Dog	10-12
Canary	20
Pigeon	20
Horse	25-30
Goose	50
Elephant	50-60
Salmon	100
Pike	150
Crocodile	175
Whale	300-400

Plants do not live forever, either. You know that annuals live only a year. Biennials live two years, and perennials live more than two years. Trees are perennials, and some of them live to be very old. In fact, trees are the oldest living things on earth. On this page is a picture of a huge cypress tree that is still growing in Mexico. Scientists have studied this tree very carefully. They believe that it is at least 5000 years old!

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1. *What would happen if a frog laid only one egg instead of hundreds of eggs?*
2. *Not all the seeds of a plant become full-grown plants. Why?*
3. *Why does the number of living things in a certain place stay about the same year after year?*
4. *Explain why the earth is not overrun with animals and plants.*
5. *Look at the list of animals on page 264. Which may live longer, a frog or a toad? A horse or an elephant? A canary or a goose?*
6. *What are the oldest living things on earth?*

Why should we help conserve living things?

YOU FOUND OUT why we must conserve the soil when you studied Unit Three. In this unit, you have learned some important things about plants and animals. You now know where new plants and animals come from, and you also know why the earth is not overrun with living things. But do you understand why we should conserve living things?

When a farmer protects his animals and plants and uses them wisely, he is helping conserve living things. Of course, he does this for a reason that anyone can easily understand. Unless he takes good care of the plants and animals on his farm, he cannot make a living for himself and his family. Conservation of farm animals and plants is just as important to us as it is to a farmer. We get most of our food and clothing from them.

But why is it important for us to conserve wild plants and wild animals? There are two good reasons. The first reason is easy to understand. *We need these living things.* You have learned how our forests and grasslands help conserve water and soil. From our forests comes wood for lumber, fuel, and paper. Trees also supply us with nuts for food and with oils and gums for paints and plastics. Our grasslands are pastures for hundreds of thousands of cows and sheep. From these animals, we get food and clothing.

In our streams, lakes, and seas are millions of animals we use for food. We eat salmon, codfish, herring, mackerel, perch, pike, trout, and many other kinds of fish. We also eat clams, oysters, lobsters, crabs, and shrimps. We use some kinds of fish to make fertilizer and glue. We often make buttons from clam shells.

We could use many kinds of wild animals that once lived in the forests, grasslands, and water of our country. But there are no longer enough of them. The Indians got much of their food and clothing from these animals. Although we still get furs from some of them, they do not provide us with much food. When the early settlers came to our country from Europe, they thought that the wild animals would last forever. For many years, they killed these animals by the thousands.

Some animals became very scarce. Huge herds of buffalo once roamed the grasslands in the western part of our country. Then hunters slaughtered the buffalo for their meat and hides. In a little over ten years, nearly 5 million buffalo were killed. Today, there are only a few thousand left. Deer, elk, bear, beavers, minks, and otters also became scarce. So did wild birds, such as pheasants, quail, geese, and ducks. Some kinds of birds disappeared entirely. Today there is not one passenger pigeon nor one heath hen still living.

Feeding deer in winter when it is hard for them to get food, is one way in which people help conserve our wild animals.

When the early settlers plowed up the grasslands and destroyed the forests, many wild animals had no place to live. You know how hard it is for living things to get what they need to grow and stay alive. So you can probably guess what happened to many other wild animals.

We need some kinds of animals because they help protect plants. Insects destroy more trees than forest fires do, and they damage many plants that provide us with food and clothing. Birds eat billions of these insects every year. Frogs, toads, and fish also eat insects. Snakes and skunks eat many insects, too. They also eat mice and rats.

Now you can understand one reason why we should help conserve wild animals and wild plants. We need these living things, because they help us in many different ways. But there is another good reason why we should protect them and use them wisely. *We enjoy these living things.*

To some people, that does not seem like a very good reason for conserving wild plants and animals. But most of us are interested in animals and plants. You probably enjoy having a pet or making a garden. Perhaps you are collecting butterflies or different kinds of leaves. We like to walk through the woods and fields where we can see wild flowers and hear songbirds. It is fun to find spring flowers or to watch a bird building its nest. Everyone can enjoy these things for many years to come if we help conserve wild plants and animals.

Thoughtless people pick wild flowers, and many of these wild plants are disappearing. You know that flowers make seeds. If you do not pick a flower, it will make seeds. Then, the next year, the seeds may grow into new plants. When flowers such as trilliums and lady's-slippers are picked, nothing is left but the roots. The leaves grow on the same stem as the flowers. Food is made in the leaves, and this food is stored in the roots. When the leaves are picked, the plant cannot make food. So it dies.

You can see why trilliums and lady's-slippers should not be picked. Other wild flowers that should not be picked are bloodroot, fringed gentian, jack-in-the-pulpit, may apple, trailing arbutus, mountain laurel, columbine, partridge berry, wake-robin, and Dutchman's-breeches. A wild flower that grows on a long stem, such as the blue violet, may be picked more freely than other wild flowers. But only a few of the green leaves should be taken, and the roots should not be disturbed.

Some states have laws against picking certain kinds of wild flowers. In state and national parks, you cannot pick the flowers. Many states have signs along the highways, warning people not to pick wild flowers. Unless people help conserve wild flowers, there will soon be none for us to enjoy.

Many people have been interested in protecting birds. For many years, they have worked to protect the birds that help us and the birds that we enjoy. These people have helped set up places where birds can live safely and raise their young. These places are called *bird sanctuaries.* Thousands of acres of land have been made into safe homes for birds.

In the autumn, many birds fly south. Then in the spring, the birds fly back north again. We say that these birds *migrate.* Each kind of bird has its own place for spending the winter and the summer. Robins go to the southern part of our country for the winter, but ruby-throated hummingbirds and orioles fly all the way across the Gulf of Mexico to Central America.

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1. *Why should we help conserve living things?*
2. *What can you do to help conserve wild animals and plants?*
3. *What wild flowers and birds are protected by laws in your state?*
4. *A certain number of living things can live in a certain amount of space. What will probably happen if people change the place where these things live?*

QUESTIONS TO ANSWER

1. Some people believe that a horsehair will turn into a snake if it is put in water. Do you think that this is true? How could you show that your answer is correct?

2. Do all plants grow from seeds? Explain your answer.

3. What must happen before the egg in a flower can make a seed?

4. How does each of these help a flower make seeds? Pistil, wind, pollen, bee, stamen, stigma.

5. Why is a microscope helpful in discovering how flowers make seeds?

6. Sometimes fruit trees bloom so early in the spring that the blossoms freeze. Do you think that fruit will grow on these trees after the blossoms have frozen? Why?

7. Can a vegetable ever be a fruit? Explain your answer.

8. Which of these would a scientist call fruits? Radish, raspberry, potato, peach, watermelon, carrot, grape, onion. Give your reasons.

9. Where do all living things come from?

10. Why are cells called the building blocks of living things?

11. Why must we protect wild animals and plants?

12. Besides killing trees, forest fires destroy other living things. How does this happen?

THINGS TO DO

1. Get some frog's eggs from a pond. Keep them in pond water in your schoolroom and watch for them to hatch. Then put the tadpoles in the aquarium.

2. Find out how long it takes hen's eggs to hatch into chickens. Try to watch some eggs that are just hatching.

3. Look in books to find pictures of different kinds of cells.

4. Learn more about how different kinds of animals take care of their young.

5. Try to find grasshopper eggs in a garden.

6. Look at some plants that have just finished blooming. Find the parts of the flowers that are still left on the plants. Open these parts and look for the seeds.

7. Read about Luther Burbank and his work with plants.

8. Plant some seeds and watch the young plants begin to grow.

9. If you have a fern at home, find the spore cases on it.

10. Make a cutting from a geranium and watch it grow.

11. Find out about the National Association of Audubon Societies, the National Wildlife Federation, and other groups that help protect our wild plants and animals.

12. Learn the names of the birds in your community that help protect trees and other plants from insects.

13. Look at as many different kinds of flowers as you can. Find the pollen, the pistils, the stamens, and the other parts.

★ *In Unit Ten You Will Learn* ★

★ *What living things were like long ago* ★
★ *How we know what living things were like long ago* ★
★ *What scientists have discovered by studying fossils* ★
★ *How animals and plants have changed* ★
★ *Why some kinds of living things have disappeared from the earth* ★

UNIT 10

What Is the History of Living Things?

Did you ever wonder how old the earth is? Scientists are sure that it is at least 2 billion years old! Since the earth was formed, many changes have taken place. In Unit Three, you read about changes in the earth's surface. Some of the changes took place millions of years ago. Others are still going on all over the earth.

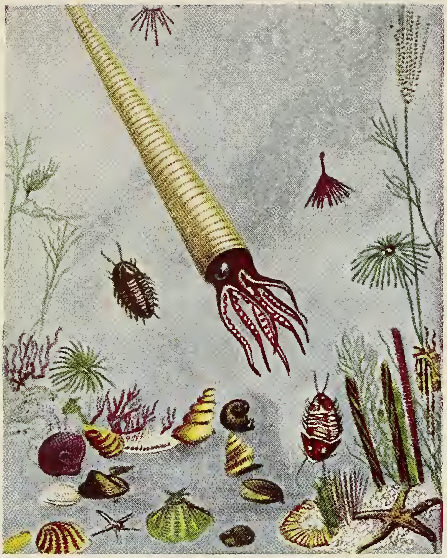
You know that erosion wears down rocks and soil and carries them away. New rocks are formed deep in the earth or under water. Then these rocks are pushed up above the surface. Again erosion wears them down. This has happened over and over again for millions of years, and it is still happening today.

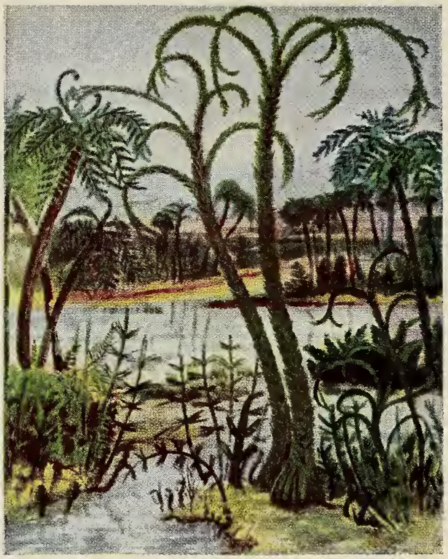
The earth's surface is not all that has changed as the years went by. Scientists know that the living things on the earth have changed, too. The plants and animals of today are very different from those that lived millions of years ago. In this unit, you will learn more about the plants and animals of long ago as you study the history of living things.

What were living things like long ago?

Suppose that on a Saturday about 500 million years ago you took a hike to find out about the animals and plants. If you looked for flowers, you would not find them. In those days, there were no plants with flowers. You could not go fishing, either, because there were no fish and you would not need field glasses to watch birds in the trees. There were no birds or trees!

You could not gather any fruits or nuts. No fruits or nuts grew in those days. And you could not collect insects. There were no insects at that time.





Perhaps you are now wondering whether there were any living things to see 500 million years ago. Yes, there were some living things. But they were very small, and they lived only in water. Imagine what the world was like when not one thing lived on the land!

All the animals and all the plants lived in the water 500 million years ago. At that time, huge seas covered half of North America. If you dipped a net into the water, you might bring up some sponges and a few jellyfish. These animals were living in those days. You might also find several kinds of animals with shells like those in the picture at the left on this page. Some of them looked much like the snails that you find in lakes and streams today.

If you rowed a boat through the water, you would not be bothered by thick reeds and other tall water plants. Plants in those days were very different from the ones of today. Most of them were very tiny plants that floated about in the water.

Now suppose that you waited about 150 million years and then took another Saturday hike. The weather 350 million years ago was very wet. You would find that the plants and animals were very different from those you saw on your first hike. This time, you might get lost in the forests of land plants that had grown up.

But you would not find trees like those of today. Most of the trees 350 million years ago looked like the ones in the picture on the right on this page. As you can see, they were huge treelike ferns. When these were covered with layers of rock, coal and oil were formed from them. You still could not see any flowers. Plants with flowers had not yet begun to grow on the earth. All plants grew from spores, just as ferns and mushrooms do today.

On this hike, you would have better luck in looking for animals. You would find many sponges, jellyfish, corals, and animals like snails. If you wanted to gather shells 350 million years ago, you could do so. You could also go fishing. So many kinds of fish lived at this time that it is often called the Age of Fishes.

You could not catch trout, bass, or sunfish. These kinds of fish did not live then. The fish of 350 million years ago looked very queer. Some were covered with big, thick scales. Their skeletons were made of tough cartilage instead of bones. Others could breathe either in water or in air, because they had both lungs and gills. Some had fins that looked almost like legs. The fish could crawl about on these fins.

This hike would have been more interesting than the one you took 150 million years before. But if you waited another 200 million years, you could take an even more interesting hike. You would find that great changes had taken place. The weather would be very dry. The seas that covered much of North America would be gone, because the land had been pushed up above the water. You would see high mountains.

As you walked along, you would find many new kinds of plants. Among them would be a kind of tree that had begun to grow since your last hike. This kind of tree is called a *cycad.* If you live in Florida or have been there, you have probably seen cycads. You may have heard them called palms or sago palms. You can see a cycad in the picture on this page.

When you look at a cycad, you are looking at one of the oldest kinds of living things on the earth. Cycad trees once grew in almost every place, but now they grow in only a few places. They were one of the first kinds of plants to have seeds. They made their seeds in cones somewhat like the cones on the pine trees of today.

You would find that the animals had changed greatly during 200 million years. On your last hike, you saw many fish and other water animals. But you did not see many land animals. Now, 200 million years later, there are many land animals. You could collect plenty of insects 150 million years ago. You could also catch amphibians such as frogs, toads, and salamanders. As you know, amphibians hatch from eggs laid in water. They spend the first part of their lives in water. When they are full-grown, they live on land as well as in water.

But you probably would not have much time to look for amphibians and small water animals, because you would be frightened by the reptiles. So many kinds of reptiles lived on the earth at this time that it is often called the Age of Reptiles. In and near the water, you would see huge turtles. But they would not frighten you so much as some of the other reptiles would. Look at the picture on this page. Giant reptiles like these roamed the earth 150 million years ago.

Many of these reptiles are called *dinosaurs*. Dinosaur means terrible lizard. The largest dinosaurs were nearly 100 feet long, and they probably weighed almost fifty tons. Some were covered with hard plates. Others had long necks and long tails. And some had sharp horns. Others walked on their hind legs and used their front legs like arms.

You might see some kinds of reptiles eating the leaves of trees and other plants. Some kinds would be catching and eating smaller animals. You would probably be surprised to see a huge animal flying over your head. Its wings would be twenty-five feet across! This animal was not a bird. It was a flying reptile.

There would be some birds, too. But you would not see any robins or crows. These kinds of birds did not live then. The birds of 150 million years ago were very different from the birds of today. They had sharp, pointed teeth. One kind of bird had a long, pointed tail with a row of feathers along each side.

You would scarcely notice the mammals. There were only a few kinds, and they were very small. Most of them were no bigger than mice. If you wanted to see many kinds of mammals, you would have to take another hike 100 million years later.

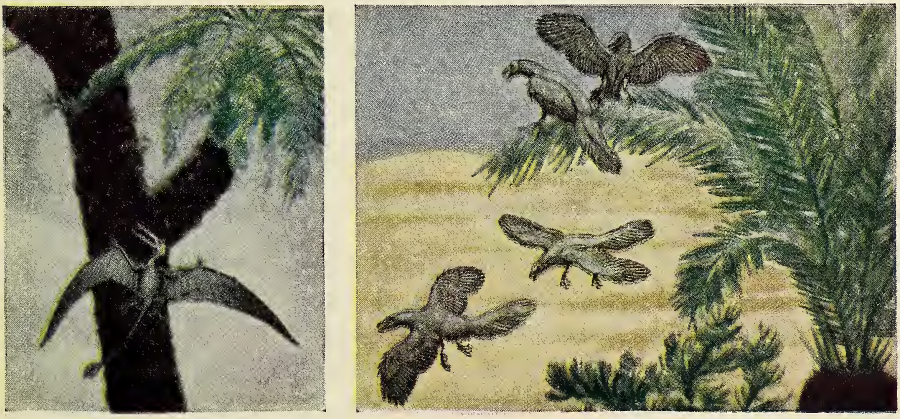
On your next hike, about 50 million years ago, you would notice that many changes had taken place. This time, you would find many kinds of plants with flowers and seeds. The fish would look much like the sharks of today. You could still find amphibians such as frogs, toads, and salamanders. But the dinosaurs and other huge reptiles would be gone. The only reptiles would look much like the snakes, turtles, and lizards that we have now. You would also notice that the birds were more like those of today.

You would find a great many kinds of mammals. That is why this time is called the Age of Mammals. Some of the mammals were very large. There were elephants, camels, and even horses. But you probably would not recognize them. They did not look like the same animals that we have now. Yet, in many ways, the animals and plants of 50 million years ago had begun to look more like those of today.

Of course, these hikes of long ago are only imaginary. But you have learned three important things as you read about the living things of the past. Let us see what these things are.

1. The earth is very, very old. Scientists think that it is at least 2 billion years old.

On the left is a flying reptile. On the right are some of the first birds.



These are some of the first horses. They were about the size of a police dog.

2. Living things have changed during millions of years. The animals and plants of today are very different from those of long ago.

3. New kinds of living things have appeared on the earth as time went by. Other kinds have disappeared.

At first, there were small plants and animals floating about in the water. Next, there were fish, then amphibians, then reptiles, then birds and mammals. For millions of years, there were no plants with seeds. The plants had spores instead of seeds. Today, there are more kinds of plants with seeds than there are kinds with spores.

You cannot expect to go out and see the different kinds of plants and animals change during your lifetime. Living things change slowly. It took many millions of years for plants and animals to become like the ones that we have now.

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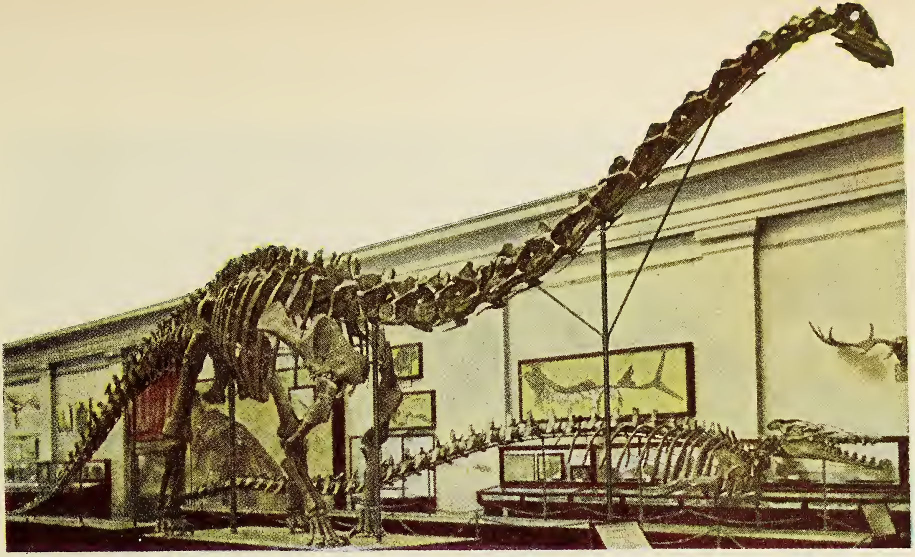
1. *What three important things did you learn in the pages that you have just read?*
2. *Look carefully at the pictures in this part of the unit. Then tell what each picture shows about the living things of long ago.*
3. *As millions of years went by, did plants and animals become more like those of today or less like them? Give some examples to show that your answer is correct.*



Scientists found the bones of these animals that once lived on the earth. When they put the bones together, they could see what the animal looked like.

How do we know what living things were like long ago?

PERHAPS YOU are saying to yourself, "How does anyone know that there were animals and plants like these long ago? No one was there to see them."

You are right if you say that no one lived 500 million years ago or even 50 million years ago. Scientists think that there have been people on the earth for no more than a million years. So, of course, there was no one to make records of what happened millions of years ago. But the animals and plants themselves made records that scientists can read.

Have you ever seen a record made by a living thing? Turn back to page 85 and look at the picture of the fish. It shows what is left of a fish that lived in the ocean millions of years ago. You remember that scientists call the hardened remains of any animal or plant a fossil. The fossil of this fish was found in a sedimentary rock 2000 feet above the ocean.

In many other rocks, scientists have found the fossils of fish and other animals that once lived in the ocean. When the animals died, their bodies settled to the bottom. Year after year, sand and mud and bones and shells settled to the bottom, too. After millions of years, these materials turned into stone. You know that limestone, sandstone, and shale were formed in this way. Scientists often find fossils in these sedimentary rocks. Only the bones, shells, and other hard parts of the bodies are left. The soft parts have all disappeared. By examining

These are the kinds of animals whose bones were found in the tar pits.

the fossils, scientists can discover how these animals must have looked.

The fossils of dead animals are found in other places besides rocks. Millions of years ago, there were huge pits of soft tar in what is now California. Scientists say that the tar was covered with water. When animals came there to drink, they walked out into the water. Their feet sank into the soft tar, and the animals could not get out. Down they went, slowly sinking deeper and deeper into the pit. After thousands of years, the tar hardened. Then, not many years ago, men dug into the hard tar and found the fossil skeletons of these animals. Nothing else was left of them.

Before glaciers covered much of the earth with ice, the northern parts of the world were warmer than they are now. Animals sometimes sank into the mud of swamps and could not get out. As the weather became colder, the swamps froze. Today, these swamps never thaw out, even in the summer. The animals are kept in a "refrigerator" of frozen mud. Scientists have found many interesting fossils in these old swamps.

Some of the fossils are skeletons of animals like the one in the picture on page 279. These animals are called mammoths, and they lived before the elephants we have now. Mammoths had long, thick hair. Their tusks were more curved than those of elephants. Fossil mammoths have been found frozen in the ice and mud. Some of them still have most of their hair, skin, and flesh over their bones.

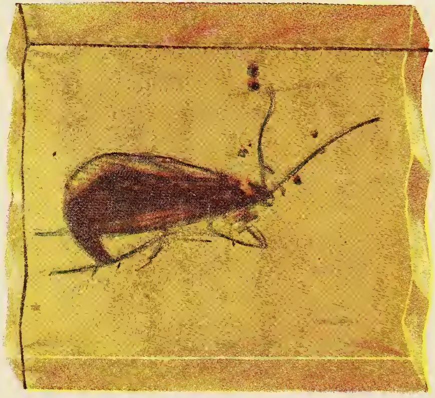
On page 279 is a picture of the body of an insect that is at least 200 million years old. One day, long ago, this insect flew against the sticky gum of a tree and was caught. The gum kept on oozing out of the tree until the insect was completely covered. As hundreds of years went by, the gum slowly hardened. It changed into a hard, transparent material called *amber*. The insect was still inside. Not many years ago, a scientist found this lump of amber. When he polished it, he saw a perfect fossil of an insect that lived long ago.

A fossil may be the whole body of an animal or plant, or it may be only a part of the animal or plant. Sometimes fossils are just footprints of animals or leafprints of plants. Have you ever seen a footprint in a cement sidewalk? A child or an animal stepped on the soft cement and made the print. When the cement hardened, the footprint became hard, too. It is a record of the person or animal that made it.

Fossils of animals and plants were often made in somewhat the same way. We call these fossils *prints*. The body of a dead animal or plant sank to the bottom of the ocean. Then it was covered with mud, sand, or other materials. It made a print in them. The soft parts of the body decayed, and sometimes the hard parts fell to pieces. But the print stayed as the materials around it changed into rock.

Sometimes the body of a dead plant or animal left a hole in the mud or other material when it decayed and fell to pieces. The hole had the same shape as the body of the animal or plant. When the hole was filled with more material, it made a *mold* of the animal or plant. Then the material was changed into rock along with the materials around it. Scientists have found many different kinds of mold fossils in sedimentary rocks.

The picture on the left shows a mammoth. On the right is a piece of amber that has an insect in it.



You can understand how fossil prints and molds were made if you do this experiment. Moisten some clay and work it with your fingers until it is soft and smooth. Then lay a shell or a leaf on the clay. Press it down until it makes a print in the clay. Lift the shell or leaf out carefully and set the clay in the sun. When the clay hardens, you will have a print like a fossil print. Now mix some plaster of Paris with a little water and pour the mixture into the print. When the plaster hardens, you can lift it out of the clay. You will have a mold of the shell or leaf that is like a mold fossil.

Fossils show us what living things were like long ago. They are records of the far-off past. Scientists have discovered thousands and thousands of fossils in all parts of the world, and every year they hunt for more. Along a roadside in Iowa, a scientist found over 10,000 fossils of small animals. Scientists once dug into a hill in Nebraska and found more than 15,000 fossil skeletons of mammals. Giant ferns left fossil prints in limestone, shale, and coal. Some cycads were buried under the soil and were *petrified*. They were changed into stone.

After scientists find a fossil, they usually send it to a museum. They sometimes have to spend hours carefully chipping bits of rock away from the fossil. If the fossil is made of many different bones, they must fit the bones together in the right way. Then they can see what the skeleton of the animal looked like.

The picture on page 277 shows a room in a museum where the fossils of animals and plants are kept. You can see the skeletons of giant reptiles that once roamed over the earth. In the museum, there are many other fossils. Some were made by small animals that crawled about in the mud at the bottom of the ocean. Some were made by queer reptiles and birds that flew about in strange trees. Others were made by plants that lived long, long ago.

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1. *Explain what a fossil is. Then give at least four different ways in which fossils are made.*
2. *How do we know what living things were like long ago?*
3. *A scientist might learn what some plants looked like 350 million years ago by studying a lump of coal. How could he do this?*
4. *Is this statement correct? Explain your answer.*
   A fossil is the body of a dead animal or plant.

What have scientists discovered by studying fossils?

SCIENTISTS SPEND a great deal of time studying fossils because they can learn many things about the far-off past. Of course, the fossils themselves show what animals and plants were like many years ago. But that is not all that they do. By studying fossils, scientists have learned much about the earth's history.

They have found out about changes in the earth's surface. They have learned how the land and the water changed. They have also discovered how the *climate* of different parts of the earth changed as the years went by. As you probably know, climate means the kind of weather that a place usually has. When the climate of a place changes, the plants and animals often change, too. As scientists studied the fossil record, they learned many things about the earth, its climate, and its living things.

Scientists have found fossils of giant ferns, cycads, and other plants as far north as Greenland. You know that almost all of this big island is now covered with a thick layer of ice. But scientists are sure that it was once covered with growing plants. The fossils show that the climate of Greenland has changed greatly since these plants lived there. Long, long ago, Greenland must have been much warmer than it is today.

In Michigan, scientists have dug up parts of coral islands. Corals are small sea animals that can live only in warm, salt water. So the land where the coral islands were discovered must once have been under warm, salt water. The sea that covered this land must have been very different from the cool, fresh water in the Great Lakes. It must have been warm and salty like the South Seas

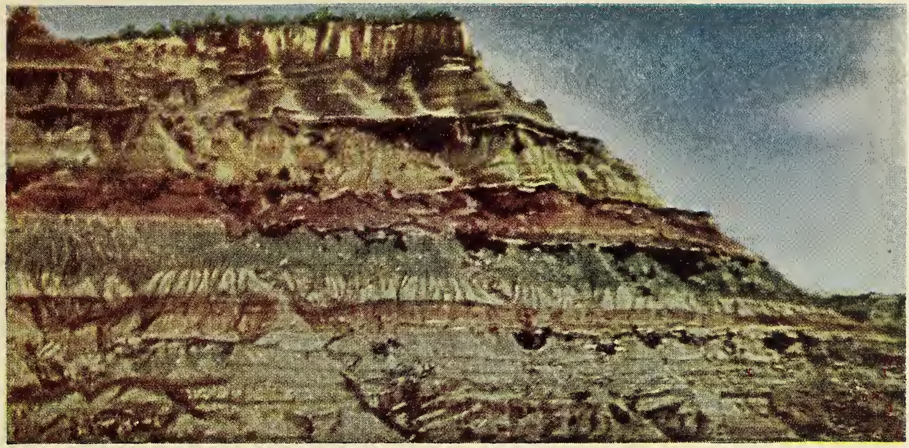
This huge fish lived 300 million years ago. The skull was found near Cleveland, Ohio. Fossils such as this tell scientists that this part of our country was once deep under water.

of the Pacific Ocean, where corals live today. Corals also live in the warm waters of the Atlantic Ocean.

Fossils not only show how the climate of places on the earth has changed. They also show how the earth's surface has changed. You remember the fossil fish shown on page 85. This fish must have lived in the ocean millions of years ago. Yet it was found high up on a mountain, many miles from salt water. In the far-off past, the part of the earth's surface where this fossil was found must have been under the ocean. Many years later, this part of the earth was pushed up. Then the water ran off, and the land is now dry.

In many places on the earth, scientists have studied the history of living things in the "book" of rocks. They have examined the rocks in the Grand Canyon of the Colorado River. Here the water of the river has cut down through the soil and rock for over a mile into the earth. Of course, it took the water millions of years to do this. As it cut down through the rock, it uncovered layer after layer of rocks made millions of years ago. In these rock layers, scientists have found the fossils of animals and plants that lived long, long ago.

Some of the rock layers are much older than others. The oldest rocks are usually found in the bottom layers, and the newest ones are near the top. You already know why this is true. As water carried mud and sand into the oceans, these rock layers were slowly built up. Year after year, sand, mud, bones, and shells settled to the

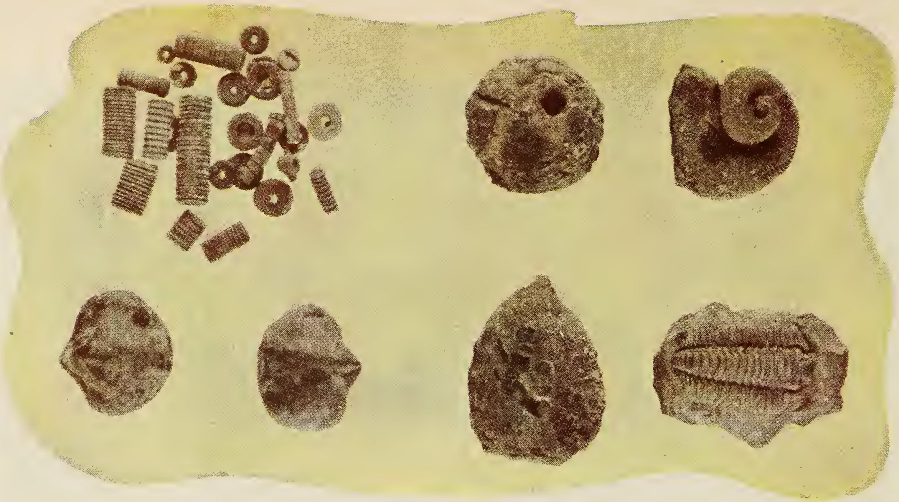


bottom. After a long time, these materials were pressed into rock. All the kinds of sedimentary rocks were made in this way.

After a layer of rock had been formed under water, a strange thing often happened. The land was pushed up, and the water ran off into lower places. The rock layer was left on dry land. Then, after millions of years, water again covered this land. Once more, a new layer of rock was slowly formed. In this layer were the fossils of that time. The land rose and sank many, many times. Each time, a new layer of sedimentary rock was formed. Scientists can easily tell the different layers of rock, because they have different colors and different fossils. A scientist has no trouble telling where one layer of rock ends and another begins.

During millions and millions of years, many layers of rock were formed where the Colorado River flows. As the river flowed along, its water cut down through these layers of rock. It cut deeper and deeper until after millions of years it made a canyon over 5000 feet deep. On the sides of the canyon, you can see the different rock layers. Many other places show the same kinds of rock layers. The oldest layers are usually found at the bottom and the newest layers near the top. Perhaps you have seen different layers of rock in the steep banks of a river or in the sides of a gravel pit.

Sometimes an older layer of rock is found on top of a newer layer. When scientists see this, they know what must have happened. Some great force must have folded the older layer over the newer one. Scientists are sure that this happened, because they find the fossils of the first animals and plants in the oldest layers



of rock. The fossils that you see in the picture on this page came from some of the oldest rock layers. They are shell animals that lived in water 500 million years ago.

Now you can understand why scientists study fossils. The fossils tell the history of animals and plants. If scientists had never found these fossils, we would not know what living things of long ago looked like. We would not know that living things have changed. If you look at the picture of some of the first birds on page 275, you can see that they are very different from the birds of today. Also look at the picture of the first trees on page 272. It is easy to see that these trees are quite different from the trees we have now.

1. *How do scientists know that Greenland was once much warmer than it is now?*
2. *Part of Michigan was once under warm, salt water. How do scientists know that this must be true?*
3. *What have scientists learned by studying fossils?*
4. *How do places like the Grand Canyon of the Colorado River help scientists discover the history of living things?*
5. *Why are the oldest rocks usually found in the bottom layers?*
6. *What would scientists know if they found these things?*
    - *a) The fossil of a sea animal on top of a mountain.*
    - *b) Fossils of sea animals and water plants in a desert.*
    - *c) Corals in the rocks of the far north.*
    - *d) Fossil ferns under a thick layer of ice.*

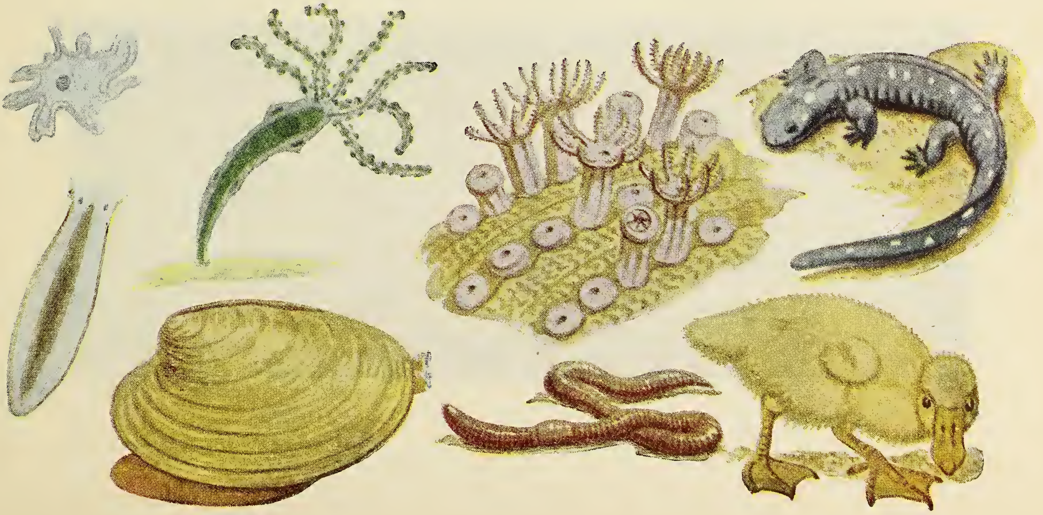
How have animals and plants changed?

You have learned that animals and plants did not always look as they do today. They have changed greatly since the first living things appeared on the earth hundreds of millions of years ago. When scientists tell about the changes in living things, they say this, "In the beginning, living things were very *simple*. Little by little, they became more *complex*." Let us see what this means.

Animals and plants are divided into several groups according to their structure. Fish belong to one of these groups. Amphibians, reptiles, birds, and mammals belong to other groups. All the animals in these groups have many, many parts in their bodies. They have bones, muscles, and many other parts. And all of the animals in these five groups have backbones. If you look at a fish, an amphibian, a reptile, a bird, or a mammal, you will find that each one has a backbone.

But there are many kinds of animals that do not have backbones. Insects, spiders, crayfish, crabs, jellyfish, sponges, and hundreds of other kinds of animals have no backbones. Also, these animals do not have so many parts in their bodies. Their bodies are simpler than the bodies of animals with backbones. Some kinds of animals are so simple that each one is made of only one cell!

On this page are some pictures that will help you see how animals have different structures. Can you find the simplest animal that is shown? It is called an *amoeba*. If you compare it with a bird or a mammal, you will see how a simple animal is different from a more complex one. The simple animal has only one part or just a few parts in its body. The more complex animal has many parts in its body. Scientists believe that the first animals had bodies with only one part.



As millions of years went by, new kinds of animals with more parts in their bodies appeared on earth. The bodies of animals became more complex.

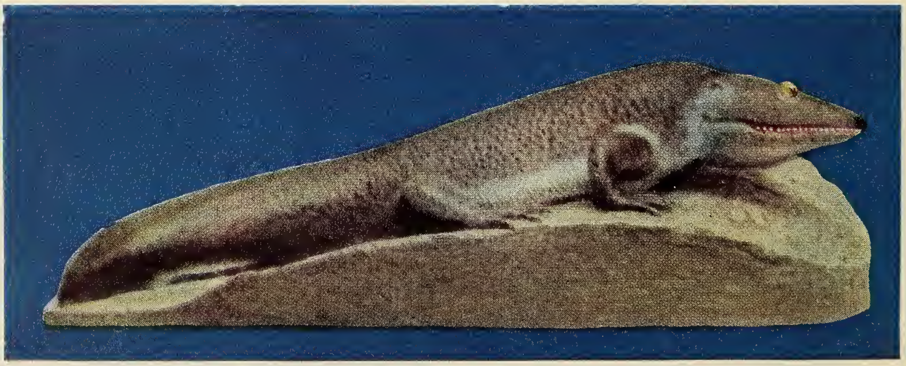
All of the fossil animals found in the oldest layers of rock were very simple animals. They had no backbones. Some of them had no hard parts at all. So they did not leave very clear records of themselves. Many of these simple animals kept on having young year after year, and they did not change. But some of these animals seem to have changed and become more complex.

In the layers just above the oldest rocks, scientists find animals that are more complex than the first animals. When you took your imaginary hike 500 million years ago, you saw sponges, jellyfish, and animals like snails in the water. These are all fairly simple animals, but they are more complex than the animals in the oldest layers of rock. They have more parts in their bodies.

Scientists find fossils of the earliest fish in the next layers of rock. On your imaginary hike 350 million years ago, you saw a great many fish. When scientists compared the fossils of these fish with the fossils of earlier animals, they found that the fish had a new part in their bodies. This part was a backbone. Fish were the first animals to have backbones. From that time on, many of the new animals that appeared had backbones.

During this very early time, there were no land animals. Then fish with both lungs and gills appeared. They could breathe both in water and in air. You remember reading about the fish with fins like legs. In the layers of rock above where these fish are found, scientists find fossils of the first amphibians. Amphibians were the first animals to crawl out of the water and live on land. Scientists believe

One of the first amphibians probably looked something like a fish with legs.



that they developed from fish that had lungs and fins like legs.

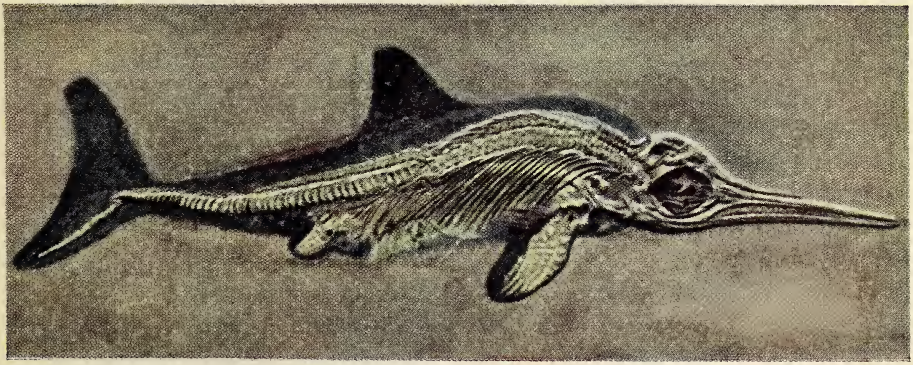
The first animals that began to live on land spent part of their life in water and part on land. You know that all amphibians still do this. You have probably watched a tadpole change from a water animal into a land animal. A tadpole hatches from an egg that was laid in water. At first, it has gills and no legs. It can live only in water. Then it grows lungs and legs. At last, it becomes a frog or a toad that can live on land.

You can understand how much any water animal had to change before it could become a land animal. It had to have new and different parts so that it could breathe and move around on land. Gills would be useless for breathing on land, and fins would be useless for traveling on land. The first land animals had to grow lungs in place of gills and legs in place of fins. Many other changes took place in the bodies of all animals that left the water and began to live on land.

After the amphibians had lived on earth for millions of years, the first reptiles appeared. Scientists discovered this by studying the different layers of rock. At one time, the reptiles were the most important animals on earth. Scientists believe that reptiles developed from amphibians. The amphibians had moist, smooth skins. They still spent part of their lives in water. The reptiles had dry, scaly skins. And they spent most of their lives on land. The scaly skins kept their bodies from drying out.

Millions of years later, a new kind of animal appeared on the earth. It was a flying reptile like the one in the picture on page 275. With its wings, it could glide through the air. The first birds had teeth like those of some reptiles. Scientists believe that birds developed from reptiles in some way. Feathers are made from the same ma-

This animal is called a fish-reptile because it is partly like a fish and partly like a reptile.



These are the fossils of ferns that lived millions of years ago.

terial as scales. So the feathers of a bird could have developed from the scales of a reptile. Of course, this wonderful change and all the other changes you are reading about took millions of years. These changes did not happen in just a few years.

Scientists believe that mammals also developed from earlier animals. As you know, all mammals have hair or fur on some parts of their skin. Hair or fur is made of the same material as the scales of a reptile. So scientists think that mammals probably developed from reptiles, as birds did. Of course, scientists have many other reasons for believing that the first mammals developed from reptiles, too. Then the first mammals changed during millions of years until they became like the mammals of today.

You know that fish, amphibians, reptiles, birds, and mammals all have backbones. Fish live in water and breathe with gills. Young amphibians do, too. Then they develop lungs and legs and crawl out on land. Reptiles, birds, and mammals all have lungs. Fish, amphibians, and reptiles are all cold-blooded. But birds and mammals are warm-blooded. Fish, amphibians, and most reptiles hatch from eggs. But some snakes and most mammals are born alive. You see that these groups of animals are alike in some ways but different in others.

When scientists compare fossil animals with the animals of today, they find that none of the fossils is exactly like any living animal. So they are sure that the animals must have changed, little by little, until they became like the ones we have now. A careful study of fossils seems to show that the more complex animals developed from the simplest animals. Fish with backbones seem to have developed from simple animals without backbones. The amphibians seem to have developed from fish, and the reptiles from the amphibians. Birds and mammals also seem to have developed from earlier animals. Probably these animals were reptiles.

Plant fossils also show that plants have changed greatly since they first appeared on earth. The earliest plants were very simple, just as the earliest animals were very simple. The first plants were made of just one cell. You would hardly think that they were plants, because they were so small. Of course, they had no leaves, stems, roots, flowers, or seeds. They were very simple, one-celled plants somewhat like the bacteria and yeasts of today. And they made new plants in much the same way. A cell grew, and then it divided to make a new plant.

Ferns, mosses, and other kinds of plants seem to have developed from these tiny one-celled plants. Mosses are made of many cells, but they do not have stems or flowers. They grow from spores instead of seeds. Ferns grow from spores, too. They have stems but no flowers. At last, plants with flowers and seeds appeared on the earth. Scientists believe that these plants developed from simpler plants, such as ferns.

A careful study of all the fossils that scientists have found seems to show one thing. The more complex animals and plants of today developed, little by little, from much simpler living things. Of course, it took millions and millions of years for this to happen.

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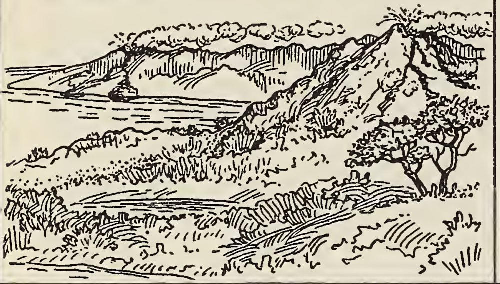
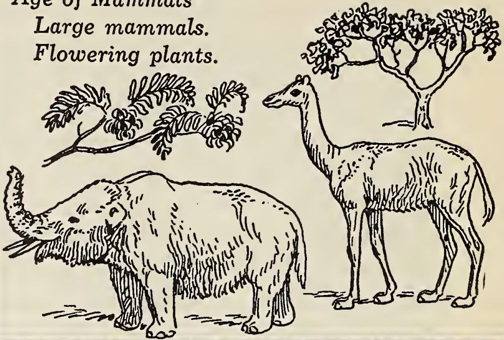
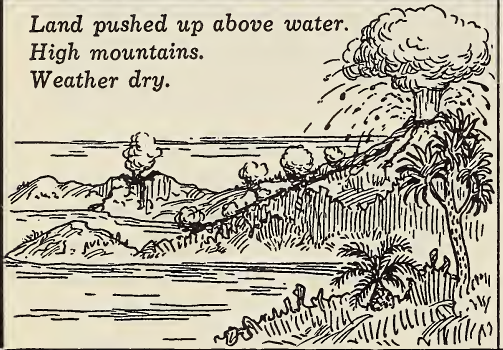
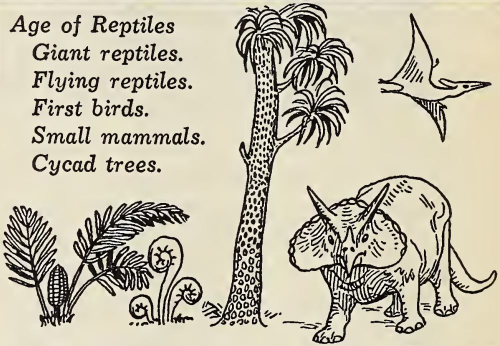
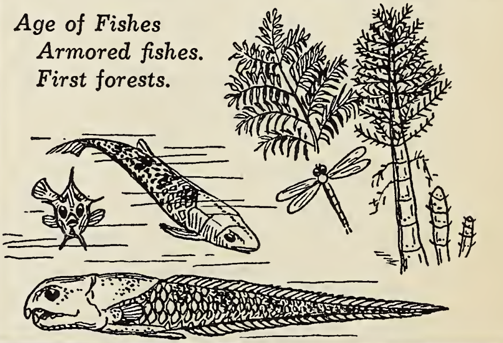
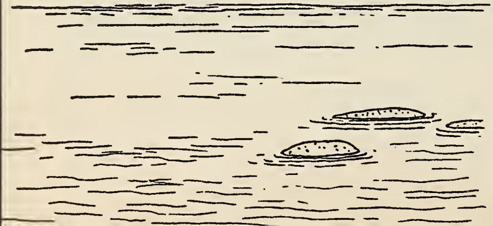
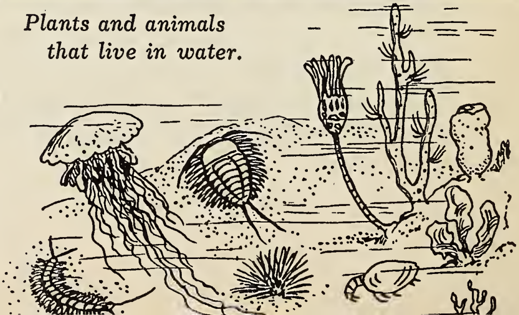
1. *Which of these animals do scientists think developed first? Explain why they think so.*
   Fish One-celled animals Reptiles Amphibians Mammals Birds
2. *How have plants changed since they first appeared on earth?*
3. *Explain what this statement means.* The more complex animals and plants seem to have developed from simpler living things.
4. *What changes had to take place in the bodies of water animals before they could live on land?*
5. *Why do scientists believe that the living things of today developed from the living things of long ago? Give as many reasons as you can.*
6. *Study the picture of the horses on page 276. How are the horses of today different from those of long ago?*

Millions of years ago	WHAT THE EARTH WAS LIKE	MOST IMPORTANT KINDS OF PLANTS AND ANIMALS
50	*Land pushed up high.* *Climate cool.* 	*Age of Mammals* *Large mammals.* *Flowering plants.* 
150	*Land pushed up above water.* *High mountains.* *Weather dry.* 	*Age of Reptiles* *Giant reptiles.* *Flying reptiles.* *First birds.* *Small mammals.* *Cycad trees.* 
350	*Much of the earth covered with sea.* *Some land pushed up above sea.* *Weather damp.* 	*Age of Fishes* *Armored fishes.* *First forests.* 
500	*Water covered most of the earth.* 	*Plants and animals that live in water.* 

Why have some kinds of living things disappeared from the earth?

During millions of years, animals and plants have changed greatly. Many new kinds of living things have appeared on the earth, and many old kinds have disappeared forever. You know that the earth itself has changed during all these millions of years. Huge seas that covered the land have disappeared. In some places, the land has been pushed up. Then the water has run down to lower places to make new seas.

The temperature of the earth has changed, too. Cold parts of the earth became warmer, and warm parts became colder. Huge glaciers covered much of the land with a thick layer of ice. Then the glaciers melted, and the water ran off into lakes and seas. Changes in the temperature made the climate change in many places. Jungles became deserts.

These changes in the land, the water, the temperature, and the climate on the earth made it necessary for living things to change. They had to change, or they could not stay alive. Scientists say that living things had to become *adapted* to their new surroundings. There were only three things that could happen to animals and plants when their surroundings changed. Let us see what these three things were.

1. Their bodies could change so that they could stay alive in their new kinds of homes.
2. They could travel to another place that was much like their old kind of home.
3. They could die if they could not change or move away.

First, let us see how their bodies could change so that they could stay alive in their new homes. Much of the land was covered with water 500 million years ago. All animals and plants lived in the water. There were no living things on the land. Then the land was slowly pushed up. Some of the seas became much shallower, and others dried up entirely. Living things had to become adapted to their new homes, or they would die.

You remember that some fish developed lungs as well as gills. These fish could breathe in water. In very shallow water, they could come to the surface and breathe in air. Other fish developed fins almost like legs. They could crawl around in shallow water where there was not enough water for swimming. You know that amphibians developed lungs and legs. Then they crawled out of the water and lived on land. They had become adapted to their new homes. Water plants also changed and became adapted to living in shallow water or on dry land. Of course, it took millions of years for these changes to happen.

Amphibians usually live where the land is wet. The hot sun would soon dry up their moist, smooth skins. But reptiles have dry, scaly skins that are thick and tough. They can live where the land is dry. As the land was pushed up, the reptiles were better adapted to their new homes than the amphibians were. Some plants were also better adapted than others. A plant that grew in a swamp could not live on dry land unless its body changed.

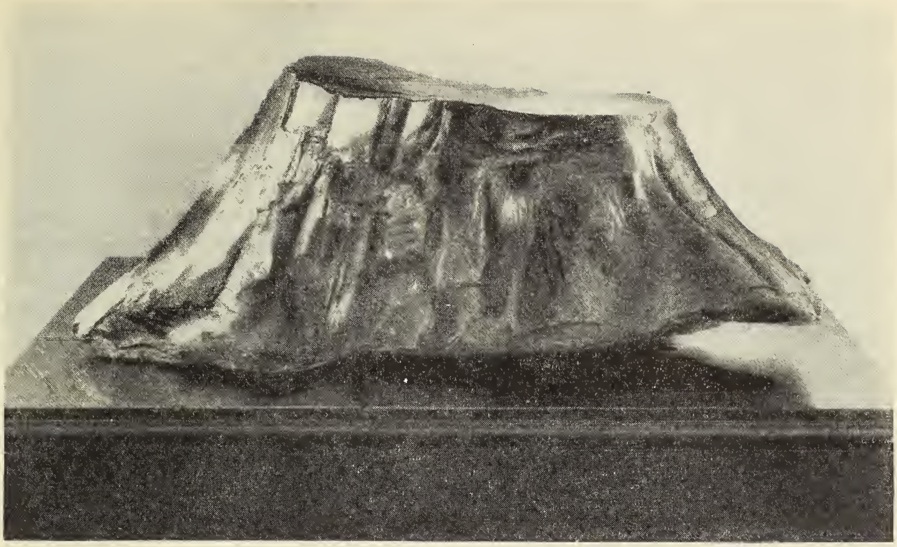
Birds and mammals are warm-blooded, and their bodies are covered with feathers or fur. But fish, amphibians, and reptiles are cold-blooded. In cold weather, they become less active. They may even stop moving and go to sleep. So when the climate became colder, the birds and mammals were better adapted to the new conditions. Some plants also have bodies that are adapted to living in cold weather. When cold weather comes, they lose their leaves, and the sap runs down into the roots.

The second thing that living things could do when their homes changed was to travel to another place. Of course, plants cannot travel. But their spores and seeds can travel. They are blown along by the wind and carried by animals. Fish and many other water animals can swim to new homes. Land animals can walk or crawl to another place. Birds can fly to another place. You know that many birds migrate in the spring and the autumn. If the weather is too cold where they are living, they fly to a warmer place. Many animals migrated to new homes when the climate changed.

But some kinds of living things could not become adapted to the changes that took place around them. They did not migrate to new homes. So they did the third thing that they could do. They died. Of course, they did not all die in one year or even in a hundred years. The changes in their surroundings usually took place very slowly. Most of the big changes took millions of years.

You know that dinosaurs and other huge reptiles were once the commonest animals on the earth. Now they are gone. They disappeared more than 100 million years ago, and only their fossils are left. Scientists do not know exactly why these animals died out. There were probably several reasons. Many of these reptiles became very big and heavy. They needed a great deal of food to stay alive. As the climate became colder, they may have become less active. Then they could not get enough to eat. Small mammals that were living then may have eaten their eggs. Jungles, deserts, mountains, and seas probably kept many of them from moving to new homes. An epidemic of some disease may have killed millions of them. Whatever the reasons were, these reptiles disappeared completely.

Many other kinds of living things have died out, too. You read about the



Millions of years ago, this tree trunk was part of a forest. The forest was gradually changed to a bed of coal. Miners digging the coal, found the stump in the mine.

fossils of mammoths that once lived on the earth. There are no mammoths living now. The huge, treelike ferns from which coal was made are also gone. They grew in swamps where the climate was warm. At one time, there were forests of these ferns growing in Alaska and near the South Pole! The climate of these places must have been much warmer than it is now. When it became colder, the plants died out. They were not adapted to the cold. They did not change, and they could not move to a new home. So they did the only thing that they could do. They died.

---

1. *When changes take place in some part of the earth, what are the three things that animals and plants can do? Tell how some animal or plant might do each one of these things.*
2. *Find two pictures in this unit which show that living things have changed. Explain what the pictures show.*
3. *Name three different changes in the earth that made it necessary for living things to change.*
4. *Explain what this statement means.* Living things had to become adapted to new surroundings.

QUESTIONS TO ANSWER

1. Do you think that fossils are being formed today? Give your reasons.

2. Why do scientists call certain times in the history of living things the Age of Fishes, the Age of Reptiles, and the Age of Mammals?

3. How were the first birds different from the birds of today?

4. How do the different layers of rock tell scientists which fossils are older than others?

5. Fossils are found in sedimentary rocks but not in igneous rocks. Explain why this is so.

6. Scientists sometimes use the fossils that they find in layers of rock to tell whether one layer is older than another. How do you think that they do this?

7. What may happen to the living things in a swamp if the water is drained from the swamp?

THINGS TO DO

1. Read more about the tar pits near Rancho La Brea, California. Learn the names of some of the fossil animals found there.

2. Look for fossils in gravel pits and other places near your home. If you find fossils, take them to school.

3. Read about the Petrified Forests in Arizona.

4. If there is a museum near your home, try to visit it and see the collection of fossils.

5. Find out how scientists think coal and oil were formed.

6. Make a chart that shows the order in which different kinds of animals appeared on the earth.

7. Find out how cactus and other plants are adapted to live in the dry climate of a desert.

8. Make a clay model of one of the old animals shown in this unit.

9. Go to a place where a highway or railroad has been cut through several layers of rock. See how many different layers you can find.

10. Find out what kinds of rocks are found in your community. What do these rocks tell a scientist about your community?

11. Read about Buffon, Lamarck, Agassiz, and other famous scientists who have studied the history of living things.

SCIENCE WORDS

CAN YOU SAY the word *dinosaur?* Do you know what it means? You can easily find out. Look in the list of science words that begins on this page. The word *dinosaur* is on page 296.

Notice that each word in the list is printed two times. The second time shows you how to say the word. Some of the letters have marks over them. The mark tells how the letter sounds. Look in the list below to see how each letter sounds.

Now look at the word *biplane* on this page. The slanting mark **′** after *bī* is bigger than the slanting mark ′ after *plān*. So you say *bi* with more force than *plān*.

a	hat, cap	ėr	term, learn	ô	order, all	ə	represents:
ā	age, face	i	it, pin	u	cup, butter	a	in about
ã	care, air	ī	ice, five	u̇	full, put	e	in taken
ä	father, far	o	hot, rock	ü	rule, move	i	in pencil
e	let, best	ō	open, go	ū	use, music	o	in lemon
ē	equal, see					u	in circus

ai ler on (ā′lər on), a movable flap on the rear edge of an airplane wing.

al ler gy (al′ər ji), a disease caused by unusual sensitiveness to certain materials.

al tim e ter (al tim′i tər), an instrument that shows how high an airplane is above the earth.

a moe ba (ə mē′bə), a very tiny animal whose body is made of just one cell.

an nu al (an′ū əl), 1. living one year. 2. a plant that lives one year.

an ti tox in (an′ti tok′sin), a material made in the blood. It changes toxins and makes them harmless.

Arc tu rus (ärk tür′əs or ärk tūr′əs), a very bright star in the northern sky.

ar ma ture (är′mə chər), the part of an electrical device that is moved by an electromagnet.

ba rom e ter (bə rom′i tər), an instrument that measures the weight of the air.

bi en ni al (bī en′i əl), 1. living two years. 2. a plant that lives two years.

bi plane (bī′plān′), an airplane that has two pairs of wings.

cir cuit (sėr′kit), the path that an electric current follows.

cir rus (sir′əs), a high cloud that may look like little curls or tufts, threads or feathers. It is made of tiny bits of ice.

cli mate (klī′mit), the kind of weather that a place usually has.

com et (kom′it), a bright object in the sky that moves around the sun in a long, oval orbit.

com plex (kom′pleks or kom pleks′), made up of a number of parts; not simple.

con duc tor (kən duk′tər), a material through which an electric current will flow.

cor pus cle (kôr′pus əl), a cell that floats in the blood. White corpuscles kill germs by eating them.

cra ter (krā′tər), the hollow place in the top of a volcano. It is shaped like a bowl.

cu mu lus (kū′mū ləs), a cloud that looks like a white puff of cotton or wool.

cy cad (sī′kad), a tree that has a cluster of fernlike leaves at the top.

Daed a lus (ded′ə ləs or dē′də ləs), a man in an old story who made wings for flying.

de-ic er (dē īs′ər), a device for removing ice on the wings and tail of an airplane.

di no saur (dī′nə sôr), one of the reptiles that lived on earth about 150 million years ago.

e clipse (i klips′), a darkening of the sun or the moon. The moon's shadow causes an eclipse of the sun. The earth's shadow causes an eclipse of the moon.

e lec tro mag net (i lek′trō mag′nit), a piece of iron that becomes a magnet when an electric current flows through a wire wound around it.

el e va tor (el′i vā′tər), the flat part that can be moved up and down in the tail of an airplane.

ep i dem ic (ep′i dem′ik), a rapid spreading of a disease so that many people have it at the same time.

e ro sion (i rō′zhən), wearing away of the earth's surface.

fil a ment (fil′ə mənt), the part of an electric-light bulb that gets hot and gives light. It is usually a very thin coil of tungsten wire.

flu o res cent (flü′ə res′ənt), able to give light when struck by certain rays.

fo cus (fō′kəs), 1. adjust (a lens) so as to make a clear picture. 2. the adjustment of a lens that makes a clear picture.

fos sil (fos′il), the hardened remains of any animal or plant.

fruit (früt), the part of a plant that contains the seeds.

fu mi gate (fū′mi gāt), treat with a poisonous gas to kill germs.

fuse (fūz), the part of an electric circuit that melts and opens the circuit when the current gets too strong.

fu se lage (fū′zə lij or fū′zə läzh′), the body of an airplane.

gal ax y (gal′ək si), a huge group of stars.

Gal i le o (gal′i lē′ō), a famous scientist who lived in Italy about 350 years ago.

ger mi cide (jėr′mi sīd), a chemical that kills germs.

gla cier (glā′shər), a huge sheet of ice that covers the land.

glid er (glīd′ər), an airplane that has no engine or propeller.

Hal ley (hal′i), Edmund, a British scientist who lived about 250 years ago.

han gar (hang′ər), a shed where airplanes are kept.

hel i cop ter (hel′i kop′tər), an airplane that has a set of rotating blades on top of the fuselage instead of wings.

hi ber nate (hī′bər nāt), stay asleep all winter.

Ic a rus (ik′ə rəs), the son of Daedalus.

ig ne ous (ig′ni əs), formed by fire.

in-line (in′līn′), with the cylinders in a straight line.

in su late (in′sə lāt or in′sū lāt), cover with an insulator.

in su la tor (in′sə lā′tər or in′sū lā′tər), a material through which an electric current will not flow; a non-conductor.

i ris (ī′ris), the colored circle around the pupil of an eye.

jet pro pul sion (jet prō pul′shən), a way of driving an airplane by a backward rush of very hot, expanding gases.

Koch (kôk), Robert, a German scientist who discovered many things about germs.

la va (lä′və or lav′ə), 1. hot, liquid rock that flows up out of the earth. 2. solid rock formed when the liquid rock cools and hardens.

Leeu wen hoek, van (lā′vən hu̇k, vän), Anton, a Dutchman who invented the microscope.

lens (lenz), a curved piece of glass that bends rays of light.

light-year (līt′yēr′), the distance that light travels in one year; about 6,000,000,000,000 miles.

met a mor phic (met′ə môr′fik), changed by great heat and pressure.

mi grate (mī′grāt), go from one place to another. Many kinds of birds migrate in the spring and the autumn.

mon o plane (mon′ə plān), an airplane that has one pair of wings.

mo raine (mə rān′), a ridge of broken rocks left at the sides or the end of a glacier.

non-con duc tor (non′kən duk′tər), a material through which an electric current will not flow; an insulator.

o paque (ō pāk′), not letting light through; not transparent or translucent.

or bit (ôr′bit), 1. the path in which a planet or a comet travels around the sun. 2. the path of a moon about a planet.

Pa ri cu tin (pä rē kü tēn′), a new volcano in Mexico.

Pas teur (päs tėr′), Louis, a French scientist who discovered many things about germs.

pen i cil lin (pen′ə sil′ən), a powerful drug that kills certain kinds of germs. It is produced by a tiny mold plant.

per en ni al (pər en′i əl), 1. living more than two years. 2. a plant that lives more than two years.

per i scope (per′i skōp), an instrument for seeing over or around things.

pet al (pet′əl), one of the parts of a flower. Petals are usually colorful.

Pe tri dish (pē′tri dish), a glass dish with a tight cover in which bacteria and other tiny plants are grown.

pet ri fy (pet′ri fī), change into stone.

pis til (pis′til), one of the parts of a flower. It produces the seeds.

pon toon (pon tün′), a boat-shaped part of an airplane that can take off and come down on water.

prism (prizm), a piece of glass with slanting sides. It bends white light and separates the light into different colors.

pu pa, plural **pu pae** (pū′pə, pū′pē), the third part in the life of some insects. A larva, such as a caterpillar, becomes a pupa and then a full-grown insect.

quar an tine (kwor′ən tēn or kwôr′ən tēn), 1. keep away from others for a time to prevent the spread of a disease. 2. the condition of being quarantined.

ra di al (rā′di əl), with the cylinders arranged like the spokes of a wheel.

ret i na (ret′i nə), delicate lining of the eyeball. When light strikes the nerves of the retina, they carry messages to the brain.

rud der (rud′ər), the flat part that can be moved from side to side in the tail of an airplane.

sanc tu ar y (sangk′chü ãr′i), a place where birds can live safely.

san i tar y (san′i tãr′i), clean and free from germs.

sed i ment (sed′i mənt), solid pieces that settle from water and sink to the bottom.

sed i men ta ry (sed′i men′tə ri), made from sediment.

se pal (sē′pəl), one of the parts of a flower. Sepals are the thin, leaflike parts that cover a bud before it opens.

se rum (sēr′əm), a liquid put into a person's body to prevent or cure a disease. It contains antitoxins made in the blood of an animal.

Sir i us (sir′i əs), the brightest star in the sky (except the sun).

so lar sys tem (sō′lər sis′təm), the sun and all the planets, moons, comets, etc., that revolve around it.

sta bi liz er (stā′bi līz′ər), a flat part in the tail of an airplane. It helps keep the airplane level.

sta men (stā′mən), one of the parts of a flower. It contains pollen.

ster i lize (ster′i līz), kill the germs in; make free from living germs.

stig ma (stig′mə), the top of the pistil of a flower. It receives the pollen.

stra tus (strā′təs), a low, gray cloud that usually covers the whole sky.

sul fa drug (sul′fə drug), any of a group of powerful drugs that kill certain kinds of germs.

su per charg er (sü′pər chär′jər), a special high-speed pump used to get more air into an engine or cabin of an airplane.

ta chom e ter (tə kom′i tər), an instrument that shows how fast an airplane engine is going.

tax i (tak′si), move (an airplane) along the ground by using the engine and propeller.

tox in (tok′sin), a poison made by a germ.

trans form er (trans fôr′mər), a device used to control an electric current.

trans lu cent (trans lü′sənt), letting light through but not transparent.

trans par ent (trans pãr′ənt), clear and easily seen through.

tri plane (trī′plān′), an airplane that has three pairs of wings.

tur bine (tėr′bin or tėr′bīn), a wheel with slanting blades. When rushing water, steam, or air strikes the blades, the wheel turns around very fast.

ty phus (tī′fəs), a deadly disease whose germs are spread by lice and fleas.

u ni verse (ū′ni vėrs), everything in the sky. The solar system is only a small part of the universe.

vac ci nate (vak′si nāt), protect with vaccine; put vaccine into.

vac cine (vak′sēn or vak′sin), a liquid put into a person's body to prevent smallpox or some other disease. The vaccine makes the blood produce antitoxins.

vi brate (vī′brāt), move back and forth very fast.

vi rus (vī′rəs), a germ that is not a plant or an animal. Viruses are so small that they cannot be seen with an ordinary microscope.

vo cal cords (vō′kəl kôrdz), the two parts in the throat that vibrate and make sounds.

vol can ic ash (vol kan′ik ash), rock that was blown to bits when a volcano erupted.

vol ca no (vol kā′nō), 1. a hole in the earth's surface from which steam, ash, and lava pour out. 2. the sloping, cone-shaped pile built up around the hole.

INDEX

IN THE NEXT FEW PAGES is a list of things that your book tells about. This list is called an *index*. You can use the index to help you find things in your book.

Notice that all the words beginning with *A* come first. All words that begin with *B* come next. Find the words that begin with *S*.

Suppose that you want to find out about bacteria. First, look for the word *bacteria* in the index. What pages in your book tell about bacteria? Look at page 96 and find out what it tells you about bacteria. What do pages 97 to 98 tell you? Does page 112 tell you about the different kinds of drugs that kill bacteria?

What are some different kinds of clouds? Are there any plants growing on Mars? Find the pages in your book that tell you.

A star after a number (like 22*) means that there is a picture on that page. What page has a picture of sandstone? What pages have pictures of comets?

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